VOLUME XLV NUMBER 4

# BOTANICAL GAZETTE

*APRIL 1908*

## THE RELATION OF PLANT SOCIETIES TO EVAPORATION

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(WITH NINE FIGURES)

During the summers of 1906 and 1907 the writer made a study of the plant societies about Cold Spring Harbor, Long Island, N. Y. In this connection an effort was made to obtain quantitative measurements of the various environmental factors upon which depend habitat differentiation and the succession of plant societies. The publication of LIVINGSTON'S paper on "The relation of desert plants to soil moisture and to evaporation" in the autumn of 1906 suggested to me that a series of vaporimeters, standardized and exposed in the various plant societies, would give comparative data that would be far more valuable than the usual temperature and relative humidity readings.

Through the kindness of DR. LIVINGSTON I was supplied with several porous cups which were standardized with the vaporimeter at Tucson. They were similar to those afterward sent out from the Desert Laboratory to various parts of the United States. For this reason the readings given in this paper may be compared directly with any obtained by other observers using these instruments.

In the nature of the case, with the small number of instruments at my disposal, it became necessary to establish one instrument as a standard for the region. Because of the desirability of having a record of the rate of evaporation in the garden of the Station for Experimental Evolution, the standard vaporimeter for my work was placed in this garden about $3^m$ east of the weather bureau instrument shelter. With this instrument all others were compared. Whenever a vaporimeter was placed in a habitat, or a reading made, a corre-

sponding reading was made of the standard vaporimeter, as nearly simultaneously as possible (*fig. 1*).

The vaporimeter consists of a porous cup supported about $1^{dm}$ above a pint jar by a glass tube which extends from the upper end of

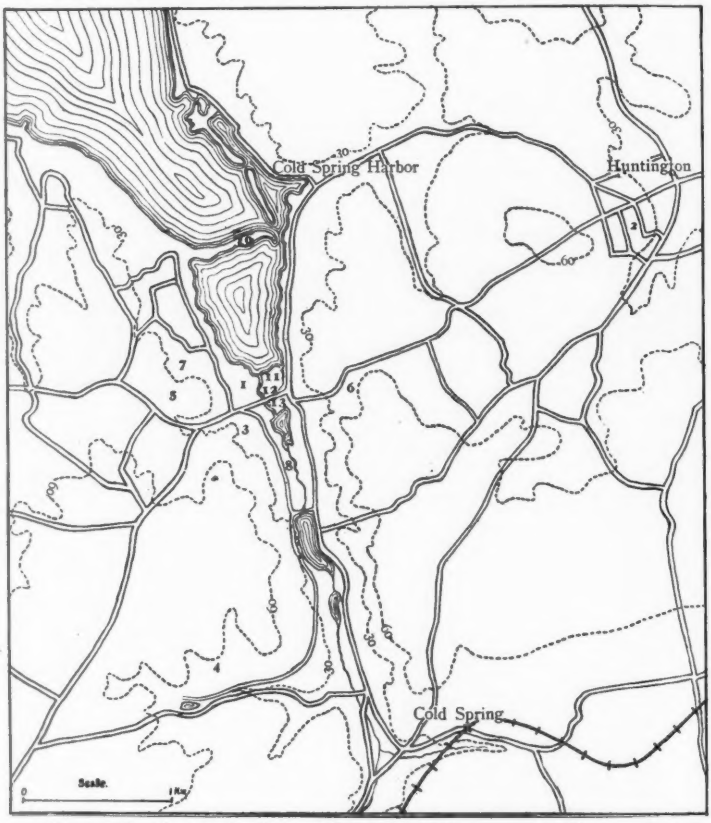



FIG. 1.—Sketch map showing positions of all stations except Station 9. Contour interval $30^{m}$.

the porous cup to the bottom of the jar. The tube is fitted air tight into the porous cup by a rubber stopper. The top of the jar is covered by a cork which is nearly air tight. Surrounding the tube above the jar is a conical shield of paraffined cloth to keep out rain. In use the jar was sunk in the ground to within $2^{cm}$ of the top. In setting up

the instrument, the porous cup and tube were completely filled with water and the jar was filled to a mark near the top. At convenient intervals the loss of water by evaporation was determined by running in water from a burette and restoring the original water level. Because of the large water area in the jar the error in these readings is estimated to be $\pm 1^{cc}$.

Following are the vaporimeter readings for the several habitats, with their accompanying vegetation. The corresponding record for the standard instrument is given in each case, together with the comparative evaporation expressed in percentages of the standard.

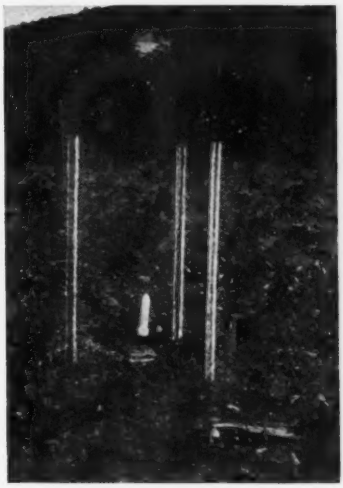


FIG. 2.—Standard instrument in position.

*Station 1* (standard).—Located in the east plot of the garden of the Station for Experimental Evolution; altitude above sea-level about $3^{m}$. During the summer the area adjacent to the vaporimeter was occupied by plants of *Oenothera nanella*, set $1^{m}$ from the instrument and from each other. The small size of this variety of evening primrose left the instrument freely exposed to the sun and air. The soil is a dark-colored sandy loam (*figs. 2, 3*).

AMOUNT OF EVAPORATION BY WEEKS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Week ending | May | 27, | $197^{cc}$ | Week ending | July | 8, | $152^{cc}$ |
| " | " | June | 3, 106 | " | " | July | 15, 152 |
| " | " | June | 10, 122 | " | " | July | 22, 114 |
| " | " | June | 17, 153 | " | " | July | 29, 160 |
| " | " | June | 24, 166 | " | " | August | 4, 102 |
| " | " | July | 1, 129 | " | " | August | 11, 104 |

Total for 12 weeks, $1657^{cc}$

*Station 2.*—A garden plot between Hillside and Highland avenues, Huntington, about $3^{km}$ east of the standard. Conditions similar to those at the Carnegie garden, except the elevation, which is about

40$^{m}$ above sea-level. Both this station and the standard were bare of vegetation at the time these comparative readings were made.

| | June 5–10 | June 10–19 | June 19–24 | Total (19 days) |
|---|---|---|---|---|
| Amt. evaporation, Station 2.... | 90.3$^{cc}$ | 145.5$^{cc}$ | 100.3$^{cc}$ | 336.1$^{cc}$ |
| Amt. evaporation, standard.... | 102.2 | 207.3 | 112.6 | 422.1 |
| Comparative evaporation.. | 88.3% | 70.1% | 89% | 79.6% |

This result indicates that for this nineteen-day period the increased elevation is correlated with decreased evaporation. This was quite unexpected, but on account of the small number of instruments at

FIG. 3.—View from Station 1 across the Carnegie garden and salt marsh.

my disposal could not be tested further. The instrument used was subsequently tested and found to be perfectly standardized, so that there is no question about the correctness of this series of readings.

*Station 3.*—Gravel slide near St. John's Episcopal Church, about 0.25$^{km}$ from the standard. The soil is a coarse sand and gravel; slopes eastward at an angle of 35°; altitude of station 25$^{m}$. The northern two-thirds of the gravel slide has been so recently disturbed by the removal of gravel, that it is free of vegetation except for some half-dead young trees which have fallen from above part way down the slope. There were none of these near the instrument. The southern third of the slide had been invaded by plants and had become

more or less stable. The vaporimeter was placed on the border between these two areas.

Growing near the instrument were the following plants in very open association: *Polytrichum* sp.? *Androgopon scoparius, Deschampsia flexuosa, Comptonia peregrina, Ionactis linearifolia, Baptisia tinctoria, Epigaea repens,* and *Vaccinium pennsylvanicum.*

FIG. 4.—Station 4; partially invaded gravel slide.

| | June 28–July 1 | July 1–8 | July 8–14 | Total (16 days) |
|---|---|---|---|---|
| Amt. evaporation, Station 3.... | 34.0cc | 140.3cc | 145.6cc | 319.9cc |
| Amt. evaporation, standard.... | 34.3 | 151.5 | 131.5 | 317.3 |
| Comparative evaporation.. | 99.1% | 92.6% | 110.7% | 100.8% |

The bare gravel slide therefore shows an evaporation approximating that of the standard. As shown by synchronous temperature records, the surface on sunshiny days rises 20° above that of the garden, but the corresponding increase in evaporation seems to be largely compensated by the somewhat lower night rate. This gravel slide station represents the pioneer stage in the reforestation of a

denuded area, and these percentages have a larger interest when compared with the stations representing later stages in this process.

FIG. 5.—Station 5; open forest on top of moraine.

*Station 4.*—Partly forested gravel slide (*fig. 4*) along the abandoned railroad grade midway between Wolfert and Tramp ponds. It is $2^{km}$ distant from Station 1; altitude $55^{m}$; slopes south at an angle of about 30°. Scrub forest vegetation has invaded this slope and formed

an open association. The principal trees (mostly under 7$^{m}$ in height) are *Pinus rigida*, *Quercus coccinea*, *Q. marylandica*, *Q. prinus*, and *Castanea dentata*. The scattered low growth consists of *Pteridium aquilinum*, *Gaylussacia resinosa*, *Vaccinium pennsylvanicum*, *Myrica carolinensis*, and *Baptisia tinctoria*. The vaporimeter was placed in the partial shade of a pine tree, surrounded by a low clump of huckleberry. Readings were made during the same periods as at Station 3.

FIG. 6.—Typical mesophytic forest with abundant undergrowth, similar to Station 6.

| | June 28–July 1 | July 1–8 | July 8–14 | Total (16 days) |
|---|---|---|---|---|
| Amt. evaporation, Station 4.... | 14.3$^{cc}$ | 103.4$^{cc}$ | 72.3$^{cc}$ | 190.0$^{cc}$ |
| Amt. evaporation, standard.... | 34.3 | 151.5 | 131.5 | 317.3 |
| Comparative evaporation.. | 41.6% | 68.2% | 54.9% | 59.5% |

Since the slope is more toward the south than at Station 3, one might expect a greater evaporation rate, other conditions being equal. But the results indicate that in spite of direction of slope, the partial invasion of the gravel slide by vegetation has produced a 40 per cent. reduction in the evaporation.

*Station 5.*—Forest on top of moraine directly west of Station 1; altitude 43$^{m}$. This wood (*fig. 5*) is composed of *Quercus prinus*, *Q. velutina*, *Q. alba*, *Fagus americana*, *Castanea dentata*, *Betula lenta*, *Hicoria glabra*, and *Acer rubrum*. The trees attain a height of 20$^{m}$.

Nearly all of the undergrowth has been removed and the forest cover is not dense.

| | July 15–23 (8 days) |
|---|---|
| Amt. evaporation, Station 5 | 71.6cc |
| Amt. evaporation, standard | 136.9 |
| Comparative evaporation | 52.2% |

When this record is compared with that of Station 4, we see that the further development of the trees to true forest proportions reduces the evaporation near the soil by an additional 10 per cent.

*Station 6.*—Forest on the Joshua Jones farm along the "short road" to Huntington, 0.5km east of the Carnegie garden. The land slopes gently to the northwest; altitude 50m.

This is a fine example of the dominant forest of the region (*fig. 6*). The principal trees are *Quercus prinus, Q. velutina, Castanea dentata, Acer rubrum, Betula lenta,* and *Fagus americana.* The shrub layer is dominated by *Kalmia latifolia,* tree seedlings, *Sassafras sassafras, Azalea nudiflora, Viburnum acerifolium, Cornus alternifolius,* and *C. florida.* The herbaceous plants are *Chimaphila maculata, Dryopteris acrostichoides, Galium circaezans, Aster cordifolius, Leptorchis liliifolia, Peramium pubescens,* and *Phegopteris.*

| | June 5–10 | June 10–19 | June 19–24 | June 24–July 2 | Total (27 days) |
|---|---|---|---|---|---|
| Amt. evaporation, Station 6 | 49.3cc | 92.1cc | 37.6cc | 50.0cc | 229.0cc |
| Amt. evaporation, standard | 102.2 | 207.3 | 112.6 | 148.8 | 570.9 |
| Comparative evaporation | 48.2% | 44.4% | 33.4% | 33.6% | 40.1% |

The important difference between this station and the last is the increased undergrowth. When the record was started the trees were just beginning to leaf out. The effect of the increased shade and interference with air movements is well shown in the 15 per cent. reduction in evaporation between the first and last part of the record. When this record is compared with others, it must be on the basis of the last two weeks. It will be noted then that as reforestation proceeds in this region, the evaporation in the lower stratum of the forest decreases from 100 per cent. to about 33 per cent. when the climax forest type is reached.

*Station 7.*—Ravine forest just south of the "North lot" of the Carnegie Institution, about 0.5km west of Station 1; altitude 10m;

soil surface slopes gradually to the northeast. This area is densely wooded and the herbaceous vegetation is very characteristic for the habitat. The trees are *Castanea dentata*, *Fraxinus americana*, *Prunus serotina*, *Betula lenta*, *Acer rubrum*, *Quercus prinus*, and *Tilia americana*. The shrub layer is made up of *Benzoin benzoin*, *Cornus florida*, *Rhus radicans*, *Viburnum acerifolium*, *Smilax rotundifolia*, and *S. herbacea*. The dominant herbs are *Washingtonia longistylis*, *Arisaema triphyllum*, *Trillium cernuum*, *Smilacina racemosa*, *Actaea*

FIG. 7.—Northern edge of swamp forest in which Station 8 was located.

*alba*, *Impatiens biflora*, *Dryopteris acrostichoides*, and *Sericocarpus asteroides*.

| | July 14–23 (9 days) |
|---|---|
| Amt. evaporation, Station 7 | 18.5$^{cc}$ |
| Amt. evaporation, standard | 141.9 |
| Comparative evaporation | 13.0% |

Here we see a further marked reduction in the evaporation rate, when compared with the wooded hilltop and slopes. The presence of Benzoin, Trillium, and Arisaema, however, is in keeping with it.

*Station 8.*—Swamp forest at the head of St. John's pond, 0.5$^{km}$ from the Carnegie garden (*fig. 7*); altitude 5$^{m}$. The soil is gravel and the water table is very near the surface. The forest cover is com-

posed of *Quercus alba, Nyssa sylvatica, Liriodendron tulipifera, Fraxinus americana.* The dense shrub layer is dominated by *Hamamelis virginiana, Viburnum molle, Azalea viscosa, Clethra alnifolia, Alnus incana, Smilax rotundifolia, Rhus radicans, Benzoin benzoin,* and *Xolisma ligustrina.* The herbaceous layer contains *Osmunda cinnamomea, Spathyaema foetida, Viola cucullata, Trillium cernuum, Dryopteris noveboracensis, Arisaema triphyllum, Carex crinita, C. Asa-Grayi, Veratum viride,* etc.

| | June 10–19 | June 19–24 | June 24–28 | Total (18 days) |
|---|---|---|---|---|
| Amt. evaporation, Station 8.... | 20.2$^{cc}$ | 11.3$^{cc}$ | 9.5$^{cc}$ | 41.0$^{cc}$ |
| Amt. evaporation, standard.... | 207.3 | 112.6 | 94.7 | 414.6 |
| Comparative evaporation.. | 9.7% | 10.0% | 10.0% | 9.9% |

This record seemed very surprising at first, but as the records from the other habitats increased, it proved to be entirely in harmony with them. During the preceding summer I took some comparative temperature and relative humidity readings for this station and the Carnegie garden. Though the temperatures ran somewhat lower and the relative humidity higher, one would scarcely have predicted an evaporation difference of 90 per cent. for the lower stratum of the two stations. The failure to take into account the relative air movements in the two situations is the probable cause of the apparent discrepancy; but the comparison helps to emphasize the importance and efficiency of the porous-cup vaporimeter as a means of differentiating habitats.

*Station 9.*—Upper beach area, on "East Beach," 3$^{km}$ north of Northport; altitude 4$^{m}$. This area is generally considered, on the basis of the vegetation, the most xerophytic along the Sound in the vicinity of Cold Spring Harbor. The direct distance from the Carnegie garden is 12$^{km}$. The vegetation is dominated by *Ammophila arundinacea, Rosa humilis, Panicum amarum, Lechea maritima, Artemisia caudata, Chrysopsis falcata, Polygonella articulata, Solidago sempervirens, Hudsonia tomentosa,* and *Opuntia opuntia.* The vaporimeter was placed among some shoots of *Rosa humilis,* just sufficiently screened so as not to attract attention. The coarse sandy substratum slopes gradually to the south at this point.

| | June 27–July 19 (22 days) |
|---|---|
| Amt. evaporation, Station 9..... | 332.1$^{cc}$ |
| Amt. evaporation, standard..... | 424.3 |
| Comparative evaporation..... | 78.2% |

*Station 10.*—Upper beach on "Sand Spit" in Cold Spring Harbor, $1^{km}$ north of the Carnegie garden; altitude $3^{m}$. The instrument was placed near the middle of the spit in the zone dominated by *Ammophila arundinacea*. Other near-by plants are *Solidago sempervirens*, *Cakile edentula*, *Asparagus officinalis*, *Euphorbia polygonifolia*, *Xanthium canadense*, *Cyperus Grayi*, *Polygonella articulata*, and *Verbascum thapsus*.

| | July 2–8 | July 8–15 | Total (13 days) |
|---|---|---|---|
| Amt. evaporation, Station 10 | 112.9cc | 138.2cc | 251.1cc |
| Amt. evaporation, standard | 131.5 | 151.9 | 283.4 |
| Comparative evaporation | 85.8% | 90.9% | 88.6% |

It will be noted that at both Stations 9 and 10 the evaporation is less than at the garden, in spite of the very xerophytic nature of the vegetation. I was unable to analyze this result further with the instruments and time at my disposal. It seems likely that the explanation lies in the low rate of evaporation during the night, due to low temperatures and increased humidity. They are more exposed to the temperature effects produced by the cooler water brought in at the flow of the tides and are more subject to fogs. The correctness of this suggestion can be tested only by an instrument which will record at hourly intervals. It is probable that the evaporation is higher on the beaches during periods of bright sunshine.

*Station 11.*—Salt marsh adjoining the garden of the Carnegie Institution. The vaporimeter was set up near the outer end of the middle line of the salt marsh (*fig. 8*). As this area is covered by water at extreme spring tides, the instrument was necessarily raised about $5^{dm}$ above the ground. The jar was protected from the sun by a heavy wrapping of felt paper. From the standpoint of the marsh vegetation the instrument stood on the tension line between the *Spartina polystachya* association and the zone dominated by *S. patens*. Other plants occurring near this point are *Atriplex hastata*, *A. arenaria*, *Tissa marina*, *Salicornia Bigelovii*, *Plantago maritima*, and *Limonium carolinianum*.

| | June 14–23 | Aug. 5–12 | Total (14 days) |
|---|---|---|---|
| Amt. evaporation, Station 11 | 175.2cc | 171.2cc | 346.4cc |
| Amt. evaporation, standard | 141.9 | 129.7 | 271.6 |
| Comparative evaporation | 123.4% | 131.9% | 127.5% |

It is here then that the greatest evaporation rate for this vicinity

was recorded. This relation was not wholly unexpected, as high temperatures and low relative humidities had been found to occur here during the preceding summer; but the amount of the excess seemed large. Preceding the second attempt at measuring this rate, all of the instruments were brought to the garden and exposed side by side for four days. Their individual factors were recalculated and found to be practically the same as those calculated by LIVINGSTON. Further,

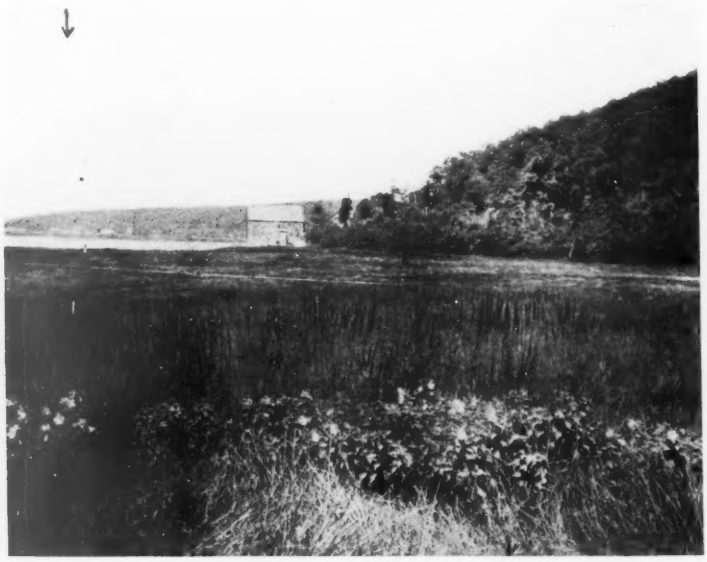


FIG. 8.—View north from road across the salt marsh; Station 11 in the distance; Station 12 at the left.

a different instrument was used for the second period. Just how this increased evaporation over the salt marsh may be accounted for is not clear. The suggestion is offered that the deposition of salt on the vegetation is effective in reducing the vapor tension of the overlying stratum of air sufficiently to raise the evaporation rate.

*Station 12.*—Inner end of salt marsh, on the tension line between the *Spartina patens–Juncus Gerardi* association and the *Scirpus americana* association (*fig. 7*). Although the tide occasionally invades this

area, the water proved by chemical test to be without a trace of chlorid at the next low tide. The vaporimeter was set up precisely as at Station 11.

| | Aug. 5–13 (8 days) |
|---|---|
| Amt. evaporation, Station 12 | 112.8cc |
| Amt. evaporation, standard | 129.7 |
| Comparative evaporation | 86.9% |

It might be urged, in connection with the high percentage reading at Station 11, that the result was due to the elevation of the instrument. This cannot be offered, however, as an explanation of the great difference between Stations 11 and 12.

The other species of plants found near the station are *Eleocharis rostellata*, *Asclepias pulchra*, *Carex gracilis*, *Lysimachia terrestris*, *Eupatorium perfoliatum*, *Hibiscus moscheutos*, and *Dryopteris thelypteris*.

*Station 13.*—Fresh-water marsh—a continuation of the same marsh in which the two preceding stations were located. A road, elevated about 3m above the marsh, separates this station from the last. I have no doubt but that this road interferes somewhat with the normal air drainage in its vicinity and may account in part for the low reading at Station 13. This station is sufficiently elevated to be beyond the reach of the highest tides. The vegetation about the instrument consisted of *Onoclea sensibilis*, *Lysimachia terrestris*, *Juncus effusus*, *Dryopteris thelypteris*, *Lycopus americana*, *Iris versicolor*, *Epilobium adenocaulon*, *Asclepias pulchra*, *Carex hystricina*. Near by grew *Acorus calamus*, *Eupatorium perfoliatum*, *Impatiens biflora*, *Ilysanthes attenuata*, *Rumex altissimus*, *Polygonum sagittatum*, *Scirpus americana*, *Myrica carolinensis*, etc.

| | Aug. 5–13 (8 days) |
|---|---|
| Amt. evaporation, Station 13 | 57.0cc |
| Amt. evaporation, standard | 129.7 |
| Comparative evaporation | 43.9% |

When we compare this record with those obtained simultaneously at the last two stations, we see that there is a further decrease of 40 per cent. as we go farther away from the outer salt marsh. Even making allowances for the interference with air currents at this station, there would be a well-marked decrease in this direction.

Putting these three station records and the standard together we see that as we go west from the middle outer portion of the salt marsh into the garden, the rate decreases by a fourth. As we go south to the edge of the salt marsh the rate is decreased nearly a half, and when the middle of the fresh-water marsh is reached the rate has decreased to one-third.

## GENERAL CONCLUSIONS

From the foregoing data, meager as they are, it is evident that we have in the porous-cup vaporimeter an instrument that will be of the greatest importance in the study of habitat conditions. Unlike so many of the recently exploited forms of instruments, it furnishes data that may be directly related to the plant. It has the great advantage over readings made from open water surfaces, in that the surface is constant and is continually exposed in the same way. Comparative readings may be obtained from different habitats by first standardizing the instruments.

The principal objection to the porous cup is its inability to withstand frost; this makes it useless in winter and early spring; it also limits its use at high elevations. Its usefulness might be greatly increased by making it self-recording, so that the diurnal variations could be accurately obtained.

The data which my observations furnish are of course characteristic only of the stratum within a meter of the soil surface. In the forest as we go from soil to tree-top this relative evaporation must increase; but it is in the lowest stratum that the seedlings, which are to determine the future of the area, have their struggle with the environment. With these data in hand it is not difficult to see why seedlings of Trillium, Arisaema, and Veratrum are successful in the swamp forest with its 10 per cent. relative evaporation; why they fail in the open hillside forest with its 50 per cent. rate; and why they are never seen on the near-by gravel slide with its relative rate of 100 per cent. in addition to its unstable character.

The following diagram (*fig. 9*) shows in a more graphic way the comparative rates of evaporation in the lowest stratum of the common habitats about Cold Spring Harbor.

In the reforestation of the gravel slides in this locality it will be seen that the greatest decrease in the demands for transpiration on the

part of seedlings takes place during the first stages. This greatly aids in accounting for the well-known fact that the development toward a closed association proceeds with such increasing rapidity when once a few plants gain a foothold. Attention has been frequently called to the importance of pioneers as shade-producers, while their effectiveness in reducing transpiration has been underestimated.

The fact that the weekly evaporation rate for a beach covered with xerophytes should be less than that for a garden may seem anomalous. But when the diminished ground-water supply, the sterility of the soil, and the probable high rate of evaporation during short periods are

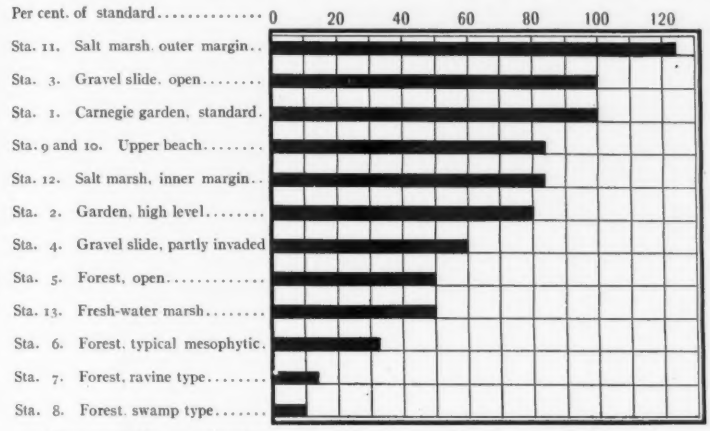



FIG. 9.—Diagram showing comparative evaporation rate in the lowest stratum of the several plant societies.

taken into account, the elimination of more mesophytic species is not surprising.

In the case of the high-level and low-level gardens further observations may alter these relative figures.

The high rate of evaporation in the salt marsh helps in the understanding of the structure of these plants.

Further work upon the rate of evaporation at different levels within the forest will aid greatly in estimating the factors involved in competition between trees. For a complete understanding of habitat conditions in general it seems essential that an instrument which will record the losses for smaller time intervals be devised.

CHARLESTON, ILL.

# FURTHER STUDIES OF SOLUTION TENSION AND TOXICITY IN LIPOLYSIS[1]

RAYMOND H. POND

This paper is really a continuation of an earlier one[2] which supplied data showing that the toxicity of certain salts in lipolysis does not vary inversely as the decomposition tension of those salts. As my conclusion disagrees with that of MATHEWS,[3] MCGUIGAN,[4] and CALDWELL,[5] and as BERG and GIES[6] found that the nature of the zymolyte is an important factor in peptolysis and tryptolysis, it seemed desirable to determine whether the same general relation found by me for the toxicity of several nitrates in the lipolysis of ethyl butyrate would also hold in the case of some other ester. Ethyl acetate was selected as the zymolyte because its saponification is a monomolecular reaction, because acetic acid is a close homologue of butyric acid, and because LOEVENHART and PEIRCE[7] found that the hydrolysis of ethyl acetate is inhibited to a greater extent by sodium fluorid than that of ethyl butyrate. They also expressed the view that the inhibiting effect of sodium fluorid is dependent upon the acid radical from which the ester is derived, while the alcohol arising in the saponification is a comparatively indifferent factor.

Since the same general procedure has been followed here as in the preceding investigation, many of the details given before will be omitted

[1] From the laboratories of the New York Botanical Garden.

[2] POND, RAYMOND H., Solution tension and toxicity in lipolysis. Amer. Jour. Physiology **19**:258–283. 1907. Contributions from the New York Botanical Garden 94.

[3] MATHEWS, A. P., The relation between solution tension, atomic volume, and the physiological action of the elements. Amer. Jour. Physiology **10**:290–323. 1904.

[4] MCGUIGAN, HUGH M., The relation between the decomposition tension of salts and their antifermentative properties. Amer. Jour. Physiology **10**:444–451. 1904.

[5] CALDWELL, J. S., The effects of toxic agents upon the action of bromelin. BOT. GAZETTE **39**:409–419. 1905.

[6] BERG, W. N., and GIES, WM. J., Studies of the effects of ions on catalysis, with particular reference to peptolysis and tryptolysis. Jour. Biol. Chem. **2**:489–546. 1907.

[7] LOEVENHART, A. S., and PEIRCE, GEO., The inhibiting effect of sodium fluorid on the action of lipase. Jour. Biol. Chem. **2**:379–413. 1907.

here. Most of the solutions used were made up from the same stock solutions and all were upon the same basis of molecular weight. The lipase used was taken from the same sample. Professor GIES has been my counselor in this work as in the other, and the same acknowledgments are due the New York Botanical Garden for the exceptionally favorable facilities afforded.

## METHOD

When ethyl acetate is decomposed by the action of lipase, the products are supposed to be the same as in any case of its saponification, namely, acetic acid and ethyl alcohol. The amount of acid liberated from initially neutral acetate under given conditions is an index of the amount of enzyme activity under those conditions, and can be expressed in cubic centimeters of KOH solution required for neutralization. Since boiling destroys the activity of the enzyme, and since the acetate does not become appreciably acid in such a boiled solution of the enzyme during an incubation of 5 hours at 40° C., a boiled solution of the enzyme can be used as a control. The difference then in acidity of a boiled and of an unboiled solution of the enzyme of equal concentration, to which the same amount of ester has been added, expresses the amount of enzyme activity under the conditions imposed. Six vials were used for each concentration of the toxic salt. To each vial were added $2^{cc}$ of the toxic salt solution of a certain concentration, say $m/32$. Then to each of three of the vials were added $2^{cc}$ of the unboiled, filtered enzyme solution having a given concentration, say 0.10 per cent. To each of the other three vials were then added $2^{cc}$ of a portion of the same enzyme solution which had been boiled. Then to each of the six vials was added $0.10^{cc}$ of neutral ethyl acetate free from alcohol. The stoppered vials were placed in an incubator for 5 hours at 40°C. After incubation each vial was titrated with $m/40$ KOH, using phenolphthalein as an indicator. The difference between the boiled and unboiled solutions showed the amount of enzyme activity for $m/64$ of the salt used with a concentration of the enzyme of about 0.05 per cent. Filtering the enzyme solution makes the exact concentration uncertain. All of the salts used were nitrates except that of mercury, which was the bichlorid.

Since the acetate has the lower boiling-point and decomposes more rapidly in the presence of water, one would expect that it would

be more readily saponified by the lipase. A 0.0125 per cent. solution of the enzyme yielded from 0.10cc of butyrate enough acid to require 0.20cc of $m/20$ KOH for neutralization. The same concentration of enzyme acting for one hour longer at the same temperature on the same amount of acetate gave the figure 0.06cc of $m/40$ KOH. A stronger solution of the enzyme (0.0250 per cent.) acting on the acetate gave 0.08cc of $m/40$ KOH. From this one might think that the butyrate is the less stable in the presence of the enzyme, but it may be that the products of saponification are more inhibiting in the one case than in the other. The concentration of the enzyme in most of

TABLE I: RELATIVE TOXICITY WITH SAME CONCENTRATION OF ENZYME

*Potassium and sodium in contemporaneous test*

| $m$ | Control[8] | Enzyme[8] | Increase[8] |
|---|---|---|---|
| **POTASSIUM** | | | |
| Water[8] | 0.07 | 0.25 | 0.18 |
| 32 | 0.06 | 0.20 | 0.14 |
| 16 | 0.06 | 0.19 | 0.13 |
| 8 | 0.06 | 0.16 | 0.10 |
| 4 | 0.06 | 0.13 | 0.07 |
| 2 | 0.06 | 0.13 | 0.07 |
| 1 | 0.06 | 0.10 | 0.04 |
| **SODIUM** | | | |
| 32 | 0.07 | 0.20 | 0.13 |
| 16 | 0.07 | 0.17 | 0.10 |
| 8 | 0.07 | 0.15 | 0.08 |
| 4 | 0.07 | 0.13 | 0.06 |
| 2 | 0.07 | 0.10 | 0.03 |
| 1 | 0.07 | 0.10 | 0.03 |

Enzyme 0.05 per cent. Incubation 5 hours at 40 C.

[8] In the column headed "$m$" are given the various concentrations of the toxic salt in fractions of molecular strength. In this column the word "Water" means that 2cc of water were used instead of the toxic solution in order to ascertain the uninhibited activity of the enzyme in 0.05 per cent. strength. In the column headed "Control" are given the figures for the final acidity (cc. $m/40$ KOH) of the boiled preparations containing the toxic salt in the concentration indicated by the corresponding figure in the column headed "$m$." The column headed "Enzyme" shows the final acidity of the unboiled preparations corresponding to the controls. The column headed "Increase" shows the difference in acidity between the controls and the unboiled preparations and expresses the amount of saponification allowed by the concentration of the toxic solution indicated by the corresponding figures in the column headed "$m$."

the tests was 0.05 per cent., that is, the filtrate obtained from the solution of $0.20^{gm}$ of the enzyme powder in $200^{cc}$ of water, filtered and then diluted one-half by the addition of an equal volume of the toxic solution. During 5 hours' incubation at 40° C., $0.1^{cc}$ of neutral acetate in $4^{cc}$ of water remains neutral.

In this test, as in several that follow, it was observed that while there was sediment in each of the vials containing boiled enzyme, the vials containing the unboiled solutions were at the close of the incubation entirely clear and free from sediment. There is no doubt therefore that partial inhibition of the enzyme is possible and actually occurs in the absence of any precipitation whatever. In this table we note that the uninhibited activity of the enzyme is expressed by $0.18^{cc}$. The most concentrated solutions of the salts reduce this to 0.04 for potassium and to 0.03 for sodium. The amount of inhibition is therefore very considerable, and yet there was no precipitation even after an incubation period of 5 hours at 40° C. In this test the nitrates of sodium and of potassium are certainly to be regarded as equitoxic.

TABLE II: *Potassium, sodium, and lithium in contemporaneous test*

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **POTASSIUM** | | | |
| Water | 0.10 | 0.25 | 0.15 |
| 8 | 0.10 | 0.15 | 0.05 |
| 4 | 0.10 | 0.13 | 0.03 |
| 1 | 0.10 | 0.13 | 0.03 |
| **SODIUM** | | | |
| 8 | 0.10 | 0.20 | 0.10 |
| 4 | 0.08 | 0.16 | 0.08 |
| 2 | 0.07 | 0.15 | 0.08 |
| 1 | 0.07 | 0.12 | 0.05 |
| **LITHIUM** | | | |
| 8 | 0.08 | 0.17 | 0.09 |
| 4 | 0.09 | 0.15 | 0.06 |
| 2 | 0.09 | 0.13 | 0.04 |

Enzyme 0.05 per cent. Incubation 4 hours at 45° C.

So far as this particular test is concerned, it can hardly be said that the salts are equitoxic. On the other hand, it cannot be positively

concluded which of the three is the most toxic. Comparison of the individuals of the series leads to nothing decisive. The next table shows that fluctuating differences occur.

TABLE III

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **POTASSIUM** | | | |
| Water | 0.09 | 0.23 | 0.14 |
| 8 | 0.10 | 0.20 | 0.10 |
| 4 | 0.09 | 0.18 | 0.09 |
| 2 | 0.09 | 0.16 | 0.07 |
| 1 | 0.09 | 0.12 | 0.03 |
| **SODIUM** | | | |
| 8 | 0.07 | 0.20 | 0.13 |
| 4 | 0.08 | 0.18 | 0.10 |
| 2 | 0.08 | 0.15 | 0.07 |
| 1 | 0.08 | 0.13 | 0.05 |
| **LITHIUM** | | | |
| 8 | 0.10 | 0.17 | 0.07 |
| 4 | 0.09 | 0.16 | 0.07 |
| 2 | 0.09 | 0.13 | 0.04 |

Enzyme 0.05 per cent. Incubation 5 hours at 45 C.

There seems to be some indication that lithium is more toxic than sodium or potassium, but the difference is too insignificant for a conclusion. In all the vials the unboiled solutions were free from sediment. Since the salt solutions themselves are neutral in all the concentrations tried, the column showing acidity of the reagent has been omitted. The titration with the *m*/40 KOH instead of the *m*/20 KOH used in the previous investigation with ethyl butyrate perhaps brings out greater variations. The acidity of the control is usually with each of these salts about the same in all concentrations and just about what the plain enzyme solution itself is. This confirms the observation made in the work with ethyl butyrate that there is no positive sign of any chemical action between the substance of the enzyme solution and that of the toxic solution.

In this test the two salts are neutral in all concentrations tried. One drop of the *m*/40 KOH gives a deep purple with $4^{cc}$ of the salt solution in any of the concentrations used in the test. The unboiled preparations were all free from sediment after incubation. Total inhi-

TABLE IV: *Barium and magnesium in contemporaneous test*

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **BARIUM** | | | |
| Water | 0.10 | 0.22 | 0.12 |
| 128 | 0.10 | 0.22 | 0.12 |
| 64 | 0.10 | 0.20 | 0.10 |
| 32 | 0.10 | 0.18 | 0.08 |
| 16 | 0.10 | 0.17 | 0.07 |
| 8 | 0.10 | 0.16 | 0.06 |
| **MAGNESIUM** | | | |
| 128 | 0.10 | 0.22 | 0.12 |
| 64 | 0.10 | 0.20 | 0.10 |
| 32 | 0.10 | 0.18 | 0.08 |
| 16 | 0.10 | 0.17 | 0.07 |
| 8 | 0.10 | 0.16 | 0.06 |

Enzyme 0.05 per cent. Incubation 4.5 hours at 40 C.

bition seems to be impossible for this concentration of the enzyme as $m/4$ of the salts is almost saturation at room temperature. In this test the two salts are certainly equitoxic.

TABLE V: *Barium and strontium in contemporaneous test*

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **BARIUM** | | | |
| Water | 0.13 | 0.27 | 0.14 |
| 128 | 0.13 | 0.27 | 0.14 |
| 64 | 0.13 | 0.24 | 0.11 |
| 32 | 0.13 | 0.22 | 0.09 |
| 16 | 0.13 | 0.20 | 0.07 |
| 8 | 0.13 | 0.16 | 0.03 |
| **STRONTIUM** | | | |
| 128 | 0.13 | 0.27 | 0.14 |
| 64 | 0.13 | 0.24 | 0.11 |
| 32 | 0.13 | 0.22 | 0.09 |
| 16 | 0.13 | 0.20 | 0.07 |
| 8 | 0.13 | 0.16 | 0.07 |

Enzyme 0.05 per cent. Incubation 5 hours at 40 C.

In this test the two salts are certainly equitoxic. Comparison with Table IV however shows inconstancy. Thus, $m/8$ of barium in Table IV allows 0.06 as compared with 0.03 in Table V. On the other hand, in both cases, $m/128$ of barium allows uninhibited activity. Again, the figure indicating full activity in Table IV is less than that in Table V, and yet $m/8$ barium inhibits more in the latter than

in the former. It is of course simply a matter of judgment how such results are to be interpreted. Since barium and strontium are equitoxic in contemporaneous tests and since the same is true of barium and magnesium, it is reasonable to conclude that the three salts are equitoxic. This same relation was found in the case of ethyl butyrate. In this table (V) the control figure is higher than that in Table IV. There is, however, a corresponding increase in the figures in the enzyme column. Just what causes such fluctuation from day to day is difficult to tell, but there seems to be sufficient uniformity in the test as a whole. For the sake of assurance another test was made, and this gave practically identical figures with those in Table IV. The figure for $m/8$ barium shows some irregularity in this next table.

TABLE VI: *Barium and magnesium in contemporaneous test*

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **BARIUM** | | | |
| Water | 0.10 | 0.23 | 0.13 |
| 128 | 0.10 | 0.22 | 0.12 |
| 64 | 0.10 | 0.20 | 0.10 |
| 32 | 0.10 | 0.17 | 0.07 |
| 16 | 0.10 | 0.16 | 0.06 |
| 8 | 0.10 | 0.13 | 0.03 |
| **MAGNESIUM** | | | |
| 128 | 0.10 | 0.22 | 0.12 |
| 64 | 0.10 | 0.20 | 0.10 |
| 32 | 0.10 | 0.18 | 0.08 |
| 16 | 0.10 | 0.16 | 0.06 |
| 8 | 0.10 | 0.16 | 0.06 |

Enzyme 0.05 per cent. Incubation 5 hours at 40 C.

In the work with ethyl butyrate I found barium, strontium, and magnesium to be equitoxic with each other, but all were more toxic than either sodium, potassium, or lithium, which latter were equitoxic with each other. In the foregoing tables there are some indications that barium, strontium, and magnesium are more toxic than the sodium, potassium, lithium group. On the other hand, the differences between lithium and magnesium are not so great. Thus, $m/8$ of lithium in Table II allows 0.09, while $m/16$ of magnesium in Table IV allows 0.07. Again, $m/8$ of lithium in Table III allows 0.07. From the foregoing tables it would be impossible to say that the barium group is more toxic than the sodium group on the equinormal basis.

It may be that the zymolyte ethyl acetate tends to minimize the difference in relative toxicity as compared with the zymolyte ethyl butyrate. While this is a plausible explanation, it has little value in the absence of convincing evidence, and we cannot select the determining factor. Why the variations in the different tests should be relatively so wide is not understood, especially in view of the precautions to avoid error.[9] The following test shows that barium is more toxic than lithium under the same conditions as imposed in a contemporaneous test. This emphasizes the apparent tendency of the barium group to exceed the sodium group in toxicity, and such a conclusion is perhaps permissible in view of all the results of this work and that on ethyl butyrate, but it would certainly be difficult to say how much more toxic.

TABLE VII: *Barium and lithium in contemporaneous test*

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **BARIUM** | | | |
| Water..... | 0.10 | 0.20 | 0.10 |
| 256..... | 0.09 | 0.16 | 0.07 |
| 128..... | 0.09 | 0.15 | 0.06 |
| 64..... | 0.09 | 0.15 | 0.06 |
| 32..... | 0.10 | 0.13 | 0.03 |
| 16..... | 0.10 | 0.12 | 0.02 |
| 8..... | 0.10 | 0.10 | 0.00 |
| **LITHIUM** | | | |
| 64..... | 0.10 | 0.20 | 0.10 |
| 32..... | 0.10 | 0.18 | 0.08 |
| 16..... | 0.10 | 0.17 | 0.07 |
| 8..... | 0.10 | 0.12 | 0.02 |
| 4..... | 0.10 | 0.11 | 0.01 |
| 2..... | 0.10 | 0.10 | 0.00 |

Enzyme 0.05 per cent. Incubation 5 hours at 40° C.

In the preceding tests it will be remembered that the salts themselves are neutral in all the concentrations used, and that the acidity of the reagent is quite uniformly the same for all the concentrations of a given salt, and that the acidity of the control is the acidity of the enzyme solution itself, as is indicated by the figure for "Water" in the control column. It is apparent that the highest saturation is required

[9] Possibly the enzyme solutions differed sufficiently to account for the discrepancies. Then too, the insolubility of the zymolyte may have been responsible to some extent.

for marked inhibition, and there is no evidence of chemical action between the enzyme substance and the toxic salt. The cause of the inhibition may be simply osmotic. In all of the remaining tests it will be noted that the toxic salt solution has more or less acidity of its own (due to hydrolytic dissociation) according to the dilution, and in several cases the control acidity is greater than the sum of the enzyme acidity and of the reagent acidity. It seems, in some cases at least, that there is chemical action between the substance of the enzyme solution and the toxic salt which results in the liberation of acid. In the higher dilutions of the toxic salt the acidity of the salt itself approaches zero, and the acidity of the control tends to be identical with that of the enzyme solution itself. Then again, at the point of total inhibition the reagent acidity and the control acidity are often equal.

TABLE VIII: *Cadmium and cobalt in contemporaneous test*

| *m* | Reagent[10] | Control | Enzyme | Increase |
|---|---|---|---|---|
| | | CADMIUM | | |
| Water..... | .... | 0.10 | 0.22 | 0.12 |
| 1024..... | 0.02 | 0.20 | 0.33 | 0.13 |
| 512..... | 0.04 | 0.30 | 0.40 | 0.10 |
| 256..... | 0.06 | 0.40 | 0.50 | 0.10 |
| 128..... | 0.10 | 0.55 | 0.60 | 0.05 |
| 64..... | 0.20 | 0.60 | 0.63 | 0.03 |
| 32..... | 0.30 | 0.90 | 0.90 | 0.00 |
| | | COBALT | | |
| 1024..... | 0.03 | 0.20 | 0.33 | 0.13 |
| 512..... | 0.06 | 0.33 | 0.43 | 0.10 |
| 256..... | 0.08 | 0.43 | 0.52 | 0.09 |
| 128..... | 0.10 | 0.70 | 0.77 | 0.07 |
| 64..... | 0.15 | 0.90 | 0.92 | 0.02 |
| 32..... | 0.30 | 1.00 | 1.00 | 0.00 |

Enzyme 0.05 per cent. Incubation 5 hours at 40 C.

All of the vials contained sediment at the close of incubation. In the unboiled $m/1024$ there was very little precipitate. Before incubation the unboiled solutions remained water clear after the mixture of enzyme and toxic salt until placed in the oven, so that the precipitation was slow.

[10] This column gives the acidity of 4cc of the toxic salt solution of the concentration indicated by the corresponding figure in the column headed "*m*."

In comparison with the preceding tables there are some points of difference here. The reagent itself is acid and the unboiled preparations show a deposit of substance which tends to be zero in quantity as the dilution of the reagent increases and the acidity consequently decreases. The point of uninhibited activity lies close to that of the lowest concentration of the toxic solution having zero acidity. The acidity of the control is greater than the sum of the reagent acidity and the acidity of the enzyme solution. In this table (VIII) it will be noted that the reagent acidity for $m/32$ cadmium is 0.30, while the corresponding control figure is 0.90. A similar relation holds for cobalt. The same relation was observed for these salts in the work on ethyl butyrate. That cadmium and cobalt are more toxic than sodium, potassium, lithium, barium, strontium, and magnesium is certain. Thus it appears that the first inhibitory effect in our series, which seems more likely to be due to chemical action than to osmotic surface tension or other physical influences, is associated with substances having a natural acidity.

TABLE IX: *Copper and zinc in contemporaneous test*

| m | Reagent | Control | Enzyme | Increase |
|---|---|---|---|---|
| **COPPER** | | | | |
| Water..... | .... | 0.07 | 0.19 | 0.12 |
| 16384..... | 0.00 | 0.10 | 0.19 | 0.09 |
| 8192..... | 0.05 | 0.13 | 0.19 | 0.06 |
| 4096..... | 0.10 | 0.17 | 0.22 | 0.05 |
| 2048..... | 0.20 | 0.23 | 0.27 | 0.04 |
| 1024..... | 0.40 | 0.40 | 0.40 | 0.00 |
| **ZINC** | | | | |
| 16384..... | 0.00 | 0.10 | 0.19 | 0.09 |
| 8192..... | 0.05 | 0.13 | 0.19 | 0.06 |
| 4096..... | 0.10 | 0.17 | 0.22 | 0.05 |
| 2048..... | 0.20 | 0.25 | 0.30 | 0.05 |
| 1024..... | 0.40 | 0.40 | 0.40 | 0.00 |

Enzyme 0.05 per cent. Incubation 5 hours at 40° C.

In this test copper and zinc are certainly equitoxic. Copper is much more active in the precipitation of substance from the solution. All the unboiled solutions with zinc were free from sediment after incubation, showing that inhibition is not necessarily associated with precipitation. In the copper solutions sediment was present in all

concentrations except $m/16384$. The amount of the precipitate varies directly with the concentration of the reagent.

TABLE X: *Copper and lead in contemporaneous test*

| $m$ | Reagent | Control | Enzyme | Increase |
|---|---|---|---|---|
| **COPPER** | | | | |
| Water | .... | 0.10 | 0.20 | 0.10 |
| 16384 | 0.00 | 0.10 | 0.20 | 0.10 |
| 8192 | 0.05 | 0.15 | 0.20 | 0.05 |
| 4096 | 0.10 | 0.18 | 0.22 | 0.04 |
| 2048 | 0.20 | 0.23 | 0.26 | 0.03 |
| 1024 | 0.40 | 0.40 | 0.40 | 0.00 |
| **LEAD** | | | | |
| 16384 | 0.00 | 0.10 | 0.20 | 0.10 |
| 8192 | 0.00 | 0.10 | 0.20 | 0.10 |
| 4096 | 0.03 | 0.15 | 0.25 | 0.10 |
| 2048 | 0.07 | 0.20 | 0.25 | 0.05 |
| 1024 | 0.16 | 0.35 | 0.40 | 0.05 |

Enzyme 0.05 per cent. Incubation 5 hours at 40 C.

All the vials except the $m/16384$ contained sediment at the close of incubation. The figures for copper are practically a duplicate of those in Table IX. Lead seems to be not quite so toxic as copper in

TABLE XI: *Copper, lead, and zinc in contemporaneous test*

| $m$ | Reagent | Control | Enzyme | Increase |
|---|---|---|---|---|
| **COPPER** | | | | |
| 4096 | 0.10 | 0.17 | 0.22 | 0.05 |
| 2048 | 0.20 | 0.23 | 0.26 | 0.03 |
| 1024 | 0.40 | 0.40 | 0.40 | 0.00 |
| 512 | 0.70 | 0.70 | 0.70 | 0.00 |
| **LEAD** | | | | |
| 4096 | 0.03 | 0.16 | 0.22 | 0.06 |
| 2048 | 0.07 | 0.24 | 0.28 | 0.04 |
| 1024 | 0.16 | 0.40 | 0.40 | 0.00 |
| 512 | 0.35 | 0.50 | 0.50 | 0.00 |
| **ZINC** | | | | |
| 4096 | 0.10 | 0.18 | 0.23 | 0.05 |
| 2048 | 0.20 | 0.26 | 0.30 | 0.04 |
| 1024 | 0.40 | 0.50 | 0.50 | 0.00 |
| 512 | 0.85 | 0.85 | 0.85 | 0.00 |

Enzyme 0.05 per cent. Incubation 5 hours at 40° C.

this test. The reagent acidity of lead is correspondingly less than that of copper, although the control figures agree fairly well with those of copper. The point of total inhibition for lead is not determined in this test, so it is not apparent whether the acidity of the reagent and control is identical at that point as was found to be the case with copper and zinc.

In this test lead proves to be equitoxic with copper and zinc. The figures for copper agree closely with those preceding. The figures for zinc agree fairly well, the important difference being that at the point of total inhibition the reagent acidity and control acidity are not identical for the $m/1024$ concentration, although at $m/512$ the coincidence may be noted. The following test is sufficient confirmation of the relation here found.

TABLE XII

| $m$ | Control | Enzyme | Increase |
|---|---|---|---|
| **COPPER** | | | |
| 4096..... | 0.13 | 0.20 | 0.07 |
| 2048..... | 0.20 | 0.23 | 0.03 |
| 1024..... | 0.40 | 0.40 | 0.00 |
| 512..... | 0.70 | 0.70 | 0.00 |
| **LEAD** | | | |
| 4096..... | 0.15 | 0.19 | 0.04 |
| 2048..... | 0.20 | 0.23 | 0.03 |
| 1024..... | 0.30 | 0.30 | 0.00 |
| 512..... | 0.50 | 0.50 | 0.00 |
| **ZINC** | | | |
| 4096..... | 0.15 | 0.20 | 0.05 |
| 2048..... | 0.23 | 0.27 | 0.04 |
| 1024..... | 0.45 | 0.45 | 0.00 |
| 512..... | 0.85 | 0.85 | 0.00 |

Enzyme 0.05 per cent. Incubation 5 hours at 40° C.

All the unboiled zinc solutions were free from sediment. The copper and the lead solutions all contained sediment, though the $m/4096$ of each contained only the smallest traces. While total inhibition may apparently occur in the absence of any precipitation, there is always (with the exception of cadmium and cobalt in Table VIII) some inhibition accompanying precipitation.

TABLE XIII: *Mercury and silver in contemporaneous test*

| *m* | Reagent | Control | Enzyme | Increase |
|---|---|---|---|---|
| **MERCURY** | | | | |
| Water..... | .... | 0.10 | 0.18 | 0.08 |
| 65536..... | 0.00 | 0.10 | 0.15 | 0.05 |
| 32768..... | 0.00 | 0.10 | 0.15 | 0.05 |
| 16384..... | 0.00 | 0.10 | 0.12 | 0.02 |
| 8192..... | 0.05 | 0.10 | 0.10 | 0.00 |
| 4096..... | 0.10 | 0.13 | 0.13 | 0.00 |
| **SILVER** | | | | |
| 32768..... | 0.00 | 0.10 | 0.15 | 0.05 |
| 16384..... | 0.00 | 0.10 | 0.13 | 0.03 |
| 8192..... | 0.00 | 0.10 | 0.13 | 0.03 |
| 4096..... | 0.00 | 0.10 | 0.12 | 0.02 |
| 2048..... | 0.00 | 0.10 | 0.10 | 0.00 |

Enzyme 0.05 per cent. Incubation 5 hours at 40 C.

In this test mercury is more toxic than silver, even on the equinormal basis, though the difference here is not nearly so great as was found with ethyl butyrate. Of course the greater concentration of the enzyme used here introduces a factor in addition to that of the different zymolyte. Mercury in comparison with silver is like copper in comparison with zinc in regard to precipitating power. The point of total inhibition is close to that of the first appearance of a precipitate,

TABLE XIV

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **MERCURY** | | | |
| 131072..... | 0.10 | 0.15 | 0.05 |
| 65536..... | 0.10 | 0.15 | 0.05 |
| 32768..... | 0.10 | 0.13 | 0.03 |
| 16384..... | 0.10 | 0.10 | 0.00 |
| 8192..... | 0.10 | 0.10 | 0.00 |
| 4096..... | 0.13 | 0.13 | 0.00 |
| **SILVER** | | | |
| 131072..... | 0.10 | 0.13 | 0.03 |
| 65536..... | 0.10 | 0.13 | 0.03 |
| 32768..... | 0.10 | 0.13 | 0.03 |
| 16384..... | 0.10 | 0.12 | 0.02 |
| 8192..... | 0.10 | 0.12 | 0.02 |
| 4096..... | 0.10 | 0.10 | 0.00 |

Enzyme 0.05 per cent. Incubation 5 hours at 40° C.

but with silver total inhibition may occur in the absence of any precipitation. The following test reinforces the result of this one.

In Table XIV the reagent acidity is omitted, as it may easily be seen in Table XIII and most of the values are zero anyhow. The relative toxicity is the same, athough the exact point of total inhibition is different. In the case of silver there was no deposit in any of the unboiled solutions, while with mercury there was deposit in $m/16384$ and in higher concentrations, while greater dilutions were free from deposit. To determine at what point precipitation first appears in the case of silver the following test was made.

TABLE XV: *Silver in solitary test*

| | SILVER | | |
|---|---|---|---|
| *m* | Control | Enzyme | Increase |
| Water..... | 0.10 | 0.15 | 0.05 |
| 262144..... | 0.10 | 0.15 | 0.05 |
| 131072..... | 0.10 | 0.15 | 0.05 |
| 65536..... | 0.10 | 0.13 | 0.03 |
| 32768..... | 0.10 | 0.13 | 0.03 |
| 16384..... | 0.10 | 0.12 | 0.02 |
| 8192..... | 0.10 | 0.12 | 0.02 |
| 4096..... | 0.10 | 0.10 | 0.00 |
| 2048..... | 0.10 | 0.10 | 0.00 |
| 1024..... | 0.15 | 0.15 | 0.00 |

Enzyme 0.05 per cent. Incubation 5 hours at 40 C.

The lowest concentration of the reagent to show any natural acidity was the $m/1024$, and greater dilutions were neutral to the indicator used. The only vials of the unboiled series to show a deposit after incubation were the $m/1024$.

A comparison of the results of this work on the acetate with those obtained in the work on ethyl butyrate shows that the same general relation holds for both. The metals fall into groups according to toxicity. The groups are not so clearly separated in the case of the acetate, but still sufficiently distinct to confirm the conclusion drawn in regard to the lipolysis of ethyl butyrate.

In the work on the ethyl butyrate it was found that the relative toxicity changes according to the concentration of the enzyme—a result not in accord with the conclusion of CALDWELL (*l. c.*). The following tests show that concentration of the enzyme is a factor in relative toxicity, and adds emphasis to my result with ethyl butyrate.

TABLE XVI

RELATIVE TOXICITY WITH VARYING CONCENTRATIONS OF THE ENZYME

*Copper and zinc in contemporaneous test*

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| | COPPER | | |
| 2048..... | 0.27 | 0.32 | 0.05 |
| 1024..... | 0.42 | 0.46 | 0.04 |
| 512..... | 0.77 | 0.80 | 0.03 |
| 256..... | 1.50 | 1.50 | 0.00 |
| 128..... | 2.90 | 2.90 | 0.00 |
| | ZINC | | |
| 2048..... | 0.30 | 0.38 | 0.08 |
| 1024..... | 0.47 | 0.53 | 0.06 |
| 512..... | 0.90 | 0.96 | 0.06 |
| 256..... | 1.73 | 1.77 | 0.04 |
| 128..... | 3.30 | 3.30 | 0.00 |

Enzyme 0.10 per cent. Incubation 5 hours at 40 C.

In Tables IX, XI, and XII, copper and zinc have the same point of total inhibition, namely $m/1024$. In those tests the concentration of the enzyme was 0.05 per cent. Here when the concentration of the enzyme is doubled the relative toxicity is changed. The point of total

TABLE XVII

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| | COPPER | | |
| 2048..... | 0.33 | 0.47 | 0.14 |
| 1024..... | 0.50 | 0.55 | 0.05 |
| 512..... | 0.80 | 0.85 | 0.05 |
| 256..... | 1950 | 1.50 | 0.00 |
| 128..... | 2.90 | 2.90 | 0.00 |
| | ZINC | | |
| 2048..... | 0.32 | 0.47 | 0.15 |
| 1024..... | 0.50 | 0.65 | 0.15 |
| 512..... | 0.87 | 1.02 | 0.15 |
| 256..... | 1.70 | 1.80 | 0.10 |
| 128..... | 3.40 | 3.50 | 0.10 |

Enzyme 0.15 per cent. Incubation 5 hours at 40 C.

inhibition for copper is $m/256$ and for zinc $m/128$. In Table XVII where the concentration of the enzyme is still higher, the difference in toxicity is more pronounced.

In the work on ethyl butyrate, cadmium, cobalt, and zinc were

found to become equitoxic with increasing concentration of the enzyme. Here the relative toxicity of zinc as compared with that of copper decreases with increasing concentration of the enzyme. In both cases the tendency of zinc to lose in relative toxicity with increasing concentration of the enzyme is apparent.

TABLE XVIII: *Mercury and silver in contemporaneous test*

MERCURY

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| 8192..... | 0.20 | 0.25 | 0.05 |
| 4096..... | 0.25 | 0.25 | 0.00 |
| 2048..... | 0.33 | 0.33 | 0.00 |
| 1024..... | 0.35 | 0.35 | 0.00 |
| 512..... | 0.53 | 0.53 | 0.00 |
| SILVER | | | |
| 8192..... | 0.20 | 0.25 | 0.05 |
| 4096..... | 0.20 | 0.24 | 0.04 |
| 2048..... | 0.20 | 0.23 | 0.03 |
| 1024..... | 0.26 | 0.26 | 0.00 |
| 512..... | 0.33 | 0.33 | 0.00 |

Enzyme 0.10 per cent. Incubation 5 hours at 40 C.

Here the point of total inhibition for copper is the same as with the lower concentration of the enzyme in the preceding table, but the zinc

TABLE XIX

MERCURY

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| 8192..... | 0.25 | 0.40 | 0.15 |
| 4096..... | 0.25 | 0.35 | 0.10 |
| 2048..... | 0.35 | 0.40 | 0.05 |
| 1024..... | 0.50 | 0.55 | 0.05 |
| 512..... | 0.85 | 0.88 | 0.03 |
| SILVER | | | |
| 8192..... | 0.25 | 0.35 | 0.10 |
| 4096..... | 0.25 | 0.35 | 0.10 |
| 2048..... | 0.25 | 0.32 | 0.07 |
| 1024..... | 0.28 | 0.33 | 0.05 |
| 512..... | 0.35 | 0.40 | 0.05 |

Enzyme 0.15 per cent. Incubation 5 hours at 40° C.

fails to inhibit totally and shows plainly that it loses toxicity faster than copper as the concentration of the enzyme increases.

In Tables XIII and XIV mercury is four times more toxic than

silver on the equimolecular basis. The same relative toxicity is maintained here as in those tables, although greater concentration of both salts is required for total inhibition.

Here the two salts are practically equitoxic, so that in some cases, with increasing concentration of the enzyme, salts, which are equitoxic become unequal in toxicity, while others that are not equitoxic under certain conditions become so under other conditions. Perhaps the only conclusion that can be safely drawn from this group of tests is that the concentration of the enzyme influences relative toxicity, and that a relation which holds for one concentration of the enzyme may not hold for another four or five times greater.

### RELATIVE TOXICITY OF EQUICATIONIC SOLUTIONS

By calculation[11] it may be determined that copper and lead of $m/2048$ concentration are equicationic, and by examination of my results it is seen that those solutions are about equitoxic. On the other hand, $m/1971$ of barium is equicationic with copper $m/2048$,

TABLE XX: ETHYL BUTYRATE

*Barium, lead, copper, and potassium in contemporaneous test*

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **BARIUM** | | | |
| Water..... | 0.00 | 0.20 | 0.20 |
| 2048..... | 0.00 | 0.20 | 0.20 |
| 1024..... | 0.00 | 0.20 | 0.20 |
| **POTASSIUM** | | | |
| 2048..... | 0.00 | 0.20 | 0.20 |
| 1024..... | 0.00 | 0.20 | 0.20 |
| **LEAD** | | | |
| 2048..... | 0.10 | 0.30 | 0.20 |
| 1024..... | 0.20 | 0.30 | 0.10 |
| **COPPER** | | | |
| 2048..... | 0.15 | 0.30 | 0.15 |
| 1024..... | 0.20 | 0.30 | 0.10 |

Enzyme .0125 per cent. Incubation 4 hours at 35° C.

[11] All of the equicationic calculations were made for me by Dr. WM. N. BERG of the Laboratory of Biological Chemistry of Columbia University.

but reference to the tables shows that such a concentration of barium is entirely without inhibitory effect upon the concentration of the enzyme tried. So by calculation it is seen that $m/2030$ of potassium is equicationic with copper $m/2048$, but reference to the table shows that potassium of such concentration is not toxic. In order to leave no doubt that cation concentration is not a determining factor in toxicity to the extent that equicationic solutions are equitoxic, the following tests were made.

According to calculation, the following solutions are equicationic: copper and lead $m/2048$, potassium $m/2030$, barium $m/1971$. Instead of making the exact concentrations for barium and potassium, it was assumed that if $m/1024$ and $m/2048$ do not inhibit, intermediate concentrations would not. Examination of the results shows that there is no basis for regarding equicationic solutions as even probably equitoxic. Neither of the concentrations of barium tried nor of potassium are inhibiting, while both of copper and one of lead are. By calculation it is easy to see that there is no fixed relation apparent between equitoxicity and equicationic concentration. The exceptions may be multiplied. Thus in the butyrate tests in my other paper, copper $m/512$ and lead $m/512$ are equicationic, equidissociated, and equitoxic. On the other hand, barium $m/8$ and copper $m/512$ are equitoxic, but the relative number of cations per unit volume of those elements in those concentrations is 38 to 1. That is, in unit volume of barium $m/8$ there are 38 cations as compared with 1 cation in unit volume of copper $m/512$. The test shown in Table XXI with ethyl acetate shows that equicationic solutions may totally inhibit or may not inhibit at all according to the salts compared.

According to the calculation from the conductivity tables, the following nitrates have a cation concentration of $m/80.7$: barium $m/64$, copper $m/70$, lead $m/64$, and potassium $m/76$. Reference to the above test shows that all of those concentrations are included within the limits of the test, and yet copper and lead totally inhibit, while barium and potassium do not inhibit at all.

## DISCUSSION

The attempt to correlate physiological action with certain physical or chemical properties either of the ions or of the atoms has thus far

been unsuccessful.[12] In view of the really large attention that has been devoted to this subject, it seems surprising that no generalization has been satisfactorily established (BERG and GIES, *l. c.*). The affinity of ions for their charges is such a fundamental property that we can hardly conceive of a chemical reaction involving solution in which this affinity or solution-tension, as some have called it, does not play a part. On the other hand, there is abundant evidence offered by my

TABLE XXI: ETHYL ACETATE

*Barium, lead, copper, and potassium in contemporaneous test*

| *m* | Control | Enzyme | Increase |
|---|---|---|---|
| **COPPER** | | | |
| Water..... | 0.12 | 0.27 | 0.15 |
| 128..... | 2.90 | 2.90 | 0.00 |
| 64..... | 5.70 | 5.70 | 0.00 |
| **LEAD** | | | |
| 128..... | 2.10 | 2.10 | 0.00 |
| 64..... | 4.20 | 4.20 | 0.00 |
| **BARIUM** | | | |
| 128..... | 0.12 | 0.27 | 0.15 |
| 64..... | 0.12 | 0.27 | 0.15 |
| **POTASSIUM** | | | |
| 128..... | 0.12 | 0.27 | 0.15 |
| 64..... | 0.12 | 0.27 | 0.15 |

Enzyme 0.10 per cent. Incubation 5 hours at 40 C.

experiments to show that there is no fixed relation between toxicity and solution-tension to the extent that the toxicity of substances can be exactly estimated from their solution-tension (POND, *l. c.* 274). There is difficulty even in agreeing upon a standard of toxicity. The minimum lethal dose measures the fatal toxicity, but is it a standard of toxicity? Does total inhibition measure the toxicity in my own experiments? In Table XIII we see that $m/16384$ and $m/32768$ of both mercury and silver are inhibiting and equally inhibiting, but for

[12] The following paper offers a recent and thorough digest of the more important literature of this subject: BERG, WM. N., The relation between the physiological action of ions and their physico-chemical properties. New York Medical Journal for July 20 and July 27, 1907. pp. 42.

total inhibition four times greater equimolecular concentration of silver is required than of mercury. (See also POND, *l. c.* 268.)

A critical examination of my own results and those of others fails to reveal any general relation without exceptions, or any property or factor that can be regarded as exclusively fundamental and as solely determining the relative toxicity of a wide series of salts.

Each of the salts I have tested is a nitrate except one, the chlorid of mercury. The members of the series fall into two groups, the neutral salts which do not hydrolytically dissociate in aqueous solution, and the hydrolytes which do so dissociate and whose solution is therefore acid or alkaline according to whether the H or OH ion is predominant. All of the hydrolytes of my series are acid, but as the dilution increases the acidity decreases to zero as here tested.

This difference between the neutral salts and the hydrolytes shows very clearly in the acidity of the controls. The controls of the neutral salts have practically the same acidity as the enzyme solution itself, that is, there is no evidence of any alteration of the acidity of the boiled enzyme solution as a consequence of the mixture with the neutral salt solution. Thus in Tables I–VII inclusive the acidity of the control is about the same for each concentration of the salt. This acidity is close to if not identical with the acidity of the plain boiled enzyme solution as indicated by the figures corresponding to "Water."

In the other tables, however, where the salts have an acid reaction in consequence of their hydrolytic dissociation, the acidity of the control and of the reagent varies considerably (POND, *l. c.* 283). Thus in Table VIII the acidity of the plain control without salt present is 0.10. The acidity of $m/1024$ cadmium is 0.02, but when the control for $m/1024$ is observed, the figure is 0.20 or considerably more than the sum of reagent and enzyme. In regard to this behavior there is much variation among the hydrolytes. Thus at the point of total inhibition the reagent acidity and control acidity may be identical, as with copper and zinc in Table IX, or considerably different, as in Table VIII with cadmium. It is difficult to interpret this with assurance.

It is notable that the neutral salts are not of equal toxicity either in the saponification of the acetate or of the butyrate (POND, *l. c.* 265, 266). Thus in Table VII barium is more toxic than lithium, so that we cannot correlate the degree of toxicity with the degree of

hydrolytic dissociation in any close way, though it is true that all of the hydrolytes in the tests I have made are more toxic than any of the neutral salts.

The fact that the hydrolytes themselves are potent in saponification has long been known, in fact the degree of hydrolysis has been measured by the rate of the saponification of esters.[13] Such salts have also been found to be potent in the inversion of sugars.[14] It was supposed that the inverting or saponifying power is associated with hydrolytic dissociation, the H or the OH ions being the active agents. LEY[15] (p. 214), however, found that KCl can invert sugar, so that other ions than those resulting from hydrolytic dissociation are potent. Thus it seems that exceptions arise to intercept the formulation of any generalization.

Significant also is the fact that dilutions of silver and mercury so great that the reaction is neutral as tested are capable of causing total inhibition. On the other hand, solutions of the neutral salts which are comparatively very concentrated are not inhibiting. Thus in Table XIII, $m/2048$ of silver is totally inhibiting but not measurably acid. In some cases we find that solutions of equal acidity are also equitoxic (Tables VIII and IX especially). This relation, however, fails in some cases (Tables X and XI). Moreover, partial or total inhibition may occur with the hydrolytes at dilutions too great to show acidity as here tested. Thus copper and zinc in Table IX show partial inhibition at $m/16384$, which is neutral, and mercury at $m/16384$ in Table XIII shows almost total inhibition without acidity, while silver in Table XIII shows total inhibition in a neutral concentration of the salt.

The relative toxicity changes as the concentration of the enzyme changes, provided the difference is enough. Thus in Tables IX, XI, and XII copper and zinc are equitoxic, but in Table XVI they are less equal, and in Table XVII still less so with the increasing concentration of the enzyme. Similar variations were found in the tests with ethyl butyrate (POND, *l. c.* 276).

[13] SHIELDS, JOHN, Ueber Hydrolysis in wässerigen Salzlösungen. Zeitsch. physikalische Chem. **12**:167–187. 1893.

[14] LONG, J. H., On the inversion of sugar by salts. Jour. Amer. Chem. Soc. **18**:120–130. 1896.

[15] LEY, H., Studien über die hydrolytische Dissociation der Salzlösungen. Zeitsch. physikalische Chem. **30**:193–257. 1899.

Just to what extent precipitation during incubation is a factor in inhibition is difficult to say. The results show that precipitation occurs in concentrations which cause total and often only partial inhibition. However, with zinc (Tables IX and XII) and silver (Tables XIV and XV) we find total inhibition without precipitation.

The enzyme itself, that is, the substance exhibiting zymolytic power, is probably a reversible colloid, and since it was not precipitated by the neutral salts used, it may be assumed to have gone into colloidal solution rather than into suspension. Perhaps it also is a hydrolyte liberating both H and OH ions. If this is the case, its saponifying power may be associated with its hydrolytic dissociation, just as has been that of the salt hydrolytes. The toxicity of the salt might even be referred to the possibility that the excess of H or of OH ions resulting from the hydrolysis of the salt prevented the hydrolytic dissociation of the enzyme substance and therefore caused the inhibition[16] (p. 214). If so, to what is the toxicity of the neutral salts to be referred? Also, why are the very highly diluted and therefore neutral solutions of silver and mercury capable of causing total inhibition? May not the chemical nature of the atom be a factor? Since convincing evidence is not available for a negative answer, and since theoretical argument based upon the negative assumption leads to embarrassing conclusions,[17] it is obvious that in any effort to discover final causes this possibility should not be ignored.

The tests with equicationic solutions show the futility of any attempt at generalization in that direction and at every hand exceptions seem to arise.

## CONCLUSION

In the zymolytic saponification of ethyl acetate as in that of ethyl butyrate, the toxicity of the salts tested does not under the conditions specified vary inversely with the decomposition tension of those salts.

The concentration of the enzyme is a factor in relative toxicity in some cases.

[16] BREDIG, G., Beiträge zur Stoichiometrie der Ionenbeweglichkeit. Zeitsch. physikalische Chem. **13**:191–288. 1894.

[17] BERG, *l. c.* pp. 15–20.

NOTE.—In referring to POND (*l. c.*), note the following errata: p. 274, bottom line, "Zinc and cadmium" should read Zinc and barium; p. 283, line 13 from top, "Table XIII" should read Table XIV.

# A QUANTITATIVE STUDY OF TRANSPIRATION

GRACE LUCRETIA CLAPP

(WITH TWO FIGURES AND THIRTY GRAPHS)

In the Laboratory of Plant Physiology of Smith College a systematic series of studies is being made to determine which of the plants available to American teachers are best for the demonstration, or investigation, of each of the principal physiological processes, and how much may be expected of them. Some of these studies in physiological constants have already been completed and others are well under way. I have undertaken to determine these facts for the process of transpiration. This work has been done under the direction of Professor W. F. GANONG, whose advice and supervision I gratefully acknowledge.

Transpiration has been extensively investigated from several points of view, and the results up to 1904 are all summarized in BURGERSTEIN'S admirable monograph.[1] It shows that investigations have been directed mainly to explain the amounts of transpiration as depending either upon structural features or upon physiological processes, or as controlled by physical changes. Special work now being done by LIVINGSTON, LLOYD, and others at the Carnegie Desert Laboratory in Arizona is likely greatly to extend our knowledge of transpiration as an ecological factor in the plant life of the desert. But nothing has as yet been done in the direction of the present study. I have not been concerned with the explanation of transpiration upon either a physical or a physiological basis, nor yet with the relations between absolute and relative transpiration, but simply with the fact that plants lose appreciable amounts of water. I have sought to determine with precision the actual amounts of water lost by plants, growing under the ordinary conditions arising in any greenhouse, and simultaneously have determined the transpiration under conditions which admit of control and repetition.

My procedure was as follows. In each species studied, two well-grown plants, of as nearly the same size as could be found, were chosen at maturity, when increase of leaf surface is at a minimum.

[1] BURGERSTEIN, ALFRED, Die Transpiration der Pflanzen. Jena. 1904.

Two or three days before use, these were brought into the experimental greenhouse, where conditions of heat, moisture, and light were practically the same as in the greenhouse proper. Any plant likely to be pot-bound was repotted in the soil mixture for common plants two or three weeks before the test, in order that it might become properly adjusted.

The actual transpiration was determined throughout by the most accurate known method, that of weighing. To prevent evaporation

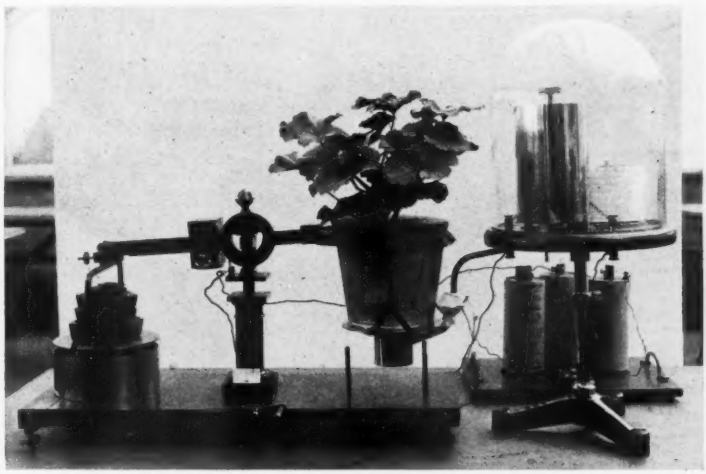


FIG. 1

from the pot and soil, each pot was covered by an aluminum or zinc shell of proper size, roofed over by rubber sheeting. This was tightly clasped to the plant, cemented along the seam, and fastened to the shell by a metal band, removable to permit the plant to be watered.

The plant to be kept under greenhouse conditions was then placed on a specially constructed balance which was brought into electrical connection with the autographic transpirometer invented by Professor GANONG and described by him in this journal.[2] The entire arrangement, slightly modified from the original form, is well shown

[2] GANONG, W. F., New precision appliances for use in plant physiology. BOT. GAZETTE 39:145. 1905.

in the accompanying *fig. 1*. By this apparatus the time and amount of transpiration are recorded continuously.

Each plant was under observation for six consecutive days (Monday morning to Saturday afternoon): climatic changes were recorded in the near vicinity by the thermograph, hygrograph, and barograph, but as changes of pressure have no appreciable effect on the transpiration the records are not given. There is no satisfactory instrument recording the varying intensities of light and darkness in a form permitting the construction of a graph. Therefore the changes of light were recorded from observation and were afterward reduced to a graph form by the following method.[3] CLEMENTS' table[4] of light intensities for the different sun altitudes (the angle of the sun's rays with a horizontal surface) for Lincoln, Neb. (41° N. lat.), was taken as a basis and changed to suit the latitude of Northampton (42° 19″ N.). Then, since the intensities for any hour of the day obtained from measurements on the celestial globe and graphically represented for a brilliant cloudless day form a parabola with greatest value at sun noon, it was possible to construct graphs showing full sunlight for each day of the year. For cloudy days the percentage of intensities was determined from the following arbitrary basis, the percentages being those of full sunlight for the given time.

| | |
|---|---|
| Slight fleecy clouds and haze | 90 per cent. |
| Heavy clouds alternating with blue sky | 85 per cent. |
| Light open clouds, shadows cast | 80 per cent. |
| Overcast, dark clouds, not rainy | 60 per cent. |
| Overcast, with dark clouds and heavy rain | 50 per cent. |
| Overcast, with dark clouds and snow | 40 per cent. |

The second plant was intended partly as a check upon results obtained from the first, but especially as a standard exposed to conditions which admit of comparison of one kind with another, and which can be repeated by other students. This plant was placed in a large glass case (*fig. 2*) of some 652 liters capacity where conditions were partly controlled, and were registered by the thermograph and hygrograph. The temperature was kept within the range of 19–21° C. and the moisture between 45 and 55 per cent. of saturation. The tempera-

[3] For aid in the calculation of the light values I wish to thank Dr. HARRIET BIGELOW of the Astronomy Department.

[4] CLEMENTS, F. E., Research methods in ecology 57. 1905.

ture was raised by an electric heater in the bottom of the case, and lowered by a metal coil, cooled by water from the street pipes, in the top of the case. To promote prompt and even warming or cooling,

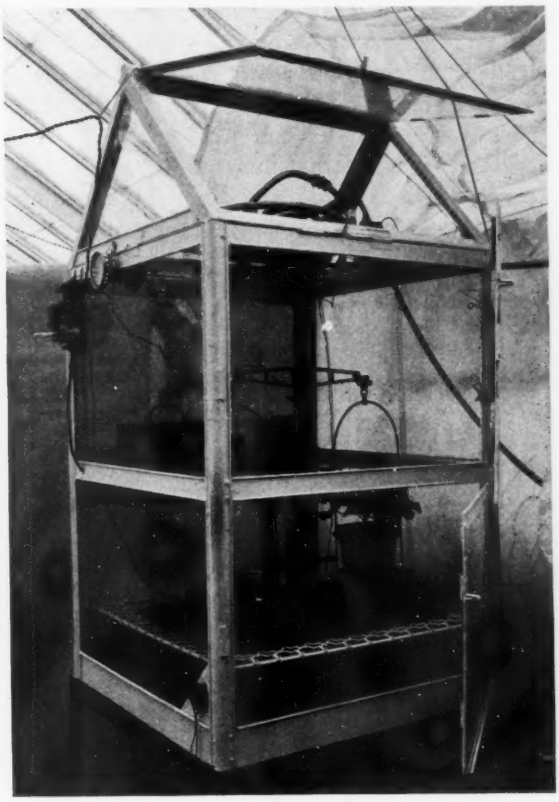


FIG. 2

electric fans of small size were made to blow air over the heating or cooling arrangements. Moisture was decreased by uncovering dishes of calcium chlorid and increased by exposing wet sponges and cloths. The case was always brought to the standard conditions, the plant was weighed and left in *still air* for as long a time as the conditions remained

within the prescribed limits; then it was weighed again, the results being reduced to an hour basis. The light was kept bright and diffuse by manipulation of a white curtain. The value of the light was considered about 90 per cent. of that received by the plant under ordinary conditions. At times when the sun did not cast a shadow both plants were exposed to the same intensity. To keep the plant under conditions of aeration as nearly normal as possible, the case was opened every morning (when the plant was watered) and the air blown out by a large electric fan.

To allow the transpiration of these plants to be compared with one another, and especially to permit the transpiration of different sizes and kinds to be compared, it was necessary to reduce their transpiration values to a common standard. For this I adopted the unit system of grams per hour per square meter of leaf surface, which for convenience may be designated the $M^2HG$ standard. Leaf area was taken for one side only and petioles were ignored unless the blade extended along the edge, when an approximate value of half the petiole was added. This system has great advantages in convenience over one in which both leaf surfaces are estimated, or in which the stems and petioles are taken into account, and since in general in any given kind of plant the amount of petiole and stem surface must be approximately proportional to the leaf surface, no error is involved in a comparative study. In certain studies, involving structural relations, etc., the stem and petiole areas would have to be considered. The surface area was computed by tracing the leaves on homogeneous paper, and weighing them after they were cut out; this value was then reduced to a square meter of surface, by the familiar method, viz., from the determination of the weight of a known unit area of the paper. Photographs of the plants kept under ordinary greenhouse conditions were made, all upon the same scale and against the same background (ruled in square centimeters). These are reproduced with their respective curves below, with the exception of three, of which the plates were accidentally destroyed.

The results of the study I have endeavored to express in the ways which will render them most useful. First in importance are the exact figures, which are contained in the following table and are reduced to average per hour. In the plant under greenhouse condi-

| Name of plant | Greenhouse conditions | | | | | | |
|---|---|---|---|---|---|---|---|
| | Actual loss per hour | | | | Area of plant | | |
| | Min. (g) | Average | | Max. (g) | ($m^2$) | Min. | |
| | | Day (g) | Night (g) | | | | |
| Abutilon striatum | .123 | 1.731 | .210 | 3.5 | .05463 | 2.25 | 31. |
| Begonia argentea guttata | .123 | 1.861 | .356 | 3.5 | .07465 | 1.648 | 24. |
| Cestrum elegans | .22 | 1.524 | .565 | 3.09 | .06383 | 3.445 | 23. |
| Chrysanthemum frutescens | .91 | 9.903 | 2.069 | 18.5 | .12849 | 7.082 | 77. |
| Cineraria stellata | .5 | 4.084 | 1.233 | 8.5 | .15866 | 3.15 | 25. |
| Coleus Blumei (var.) | .43 | 2.470 | .819 | 5.09 | .12164 | 3.53 | 20. |
| Cucurbita Pepo | .19 | 6.437 | .774 | 13. | .12420 | 1.53 | 51. |
| Euphorbia pulcherrima | .34 | 3.442 | 1.155 | 6. | .07372 | 4.61 | 46 |
| Ficus elastica | .153 | 2.882 | .502 | 4.33 | .07070 | 2.16 | 40 |
| Fuchsia speciosa | .45 | 5.526 | 1.128 | 11. | .09976 | 4.51 | 55 |
| Hedera Helix | .08 | 1.656 | .213 | 3.09 | .07090 | 1.128 | 23 |
| Helianthus annuus | .386 | 6.670 | .974 | 13. | .05056 | 7.634 | 131 |
| Heliotropium peruvianum | .83 | 4.355 | 1.441 | 9. | .13009 | 6.38 | 33 |
| Impatiens Holstii | .21 | .946 | .280 | 5. | .02383 | 4.74 | 27 |
| Ipomoea purpurea | .084 | 4.783 | .434 | 8.5 | .06665 | 1.26 | 71 |
| Lupinus albus | .119 | 2.855 | .344 | 5. | .03615 | 3.29 | 78 |
| Lycopersicum esculentum | .18 | 8.085 | .803 | 15.5 | .10673 | 1.686 | 75 |
| Pelargonium domesticum | .116 | 5.156 | .497 | 12.5 | .08657 | 1.339 | 59 |
| Pelargonium peltatum | .169 | 3.600 | .446 | 7. | .07065 | 2.392 | 50 |
| Pelargonium zonale | .44 | 6.940 | 1.135 | 17. | .14794 | 2.97 | 46 |
| Phaseolus vulgaris | .3 | 2.348 | .623 | 6.5 | .06878 | 4.36 | 34 |
| Primula sinensis | .155 | 1.242 | .375 | 2.77 | .07452 | 2.799 | 16 |
| Ricinus communis | .29 | 1.694 | .563 | 5. | .06115 | 4.74 | 27 |
| Salvia involucrata | .315 | 8.313 | 1.123 | 12.5 | .13382 | 2.35 | 62 |
| Senecio mikanioides | .21 | 3.126 | .737 | 8. | .06309 | 3.328 | 49 |
| Senecio Petasitis | .57 | 9.708 | 2.492 | 19. | .14581 | 3.909 | 66 |
| Tradescantia zebrina | .105 | .819 | .166 | 1.45 | .02610 | 4.023 | 31 |
| Tropaeolum majus | .1 | 9.668 | 1.813 | 15. | .12801 | 7.81 | 75 |
| Vicia Faba | .129 | 2.296 | .258 | 4.67 | .04117 | 3.13 | 55 |
| Zea Mays | .195 | 5.560 | .703 | 12. | .12655 | 1.541 | 43 |

| NDITIONS | | | | STANDARD CONDITIONS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M²HG | | | Actual loss per hour | | | Area of plant | M²HG | | |
| Min. | Average Day | Average Night | Max. | Min. (g) | Average Day (g) | Max. (g) | ($m^2$) | Min. | Average Day | Max. |
| 2.25 | 31.680 | 3.839 | 64.06 | .36 | 1.334 | 2.4 | .05002 | 7.19 | 26.669 | 47.98 |
| 1.648 | 24.947 | 4.776 | 47.05 | 1.08 | 1.375 | 1.58 | .07216 | 14.979 | 19.070 | 21.914 |
| 3.445 | 23.864 | 8.846 | 48.387 | 1. | 1.187 | 1.15 | .07043 | 14.198 | 16.860 | 16.328 |
| 7.082 | 77.069 | 16.099 | 143.98 | 6.6 | 8.830 | 12.05 | .12955 | 50.945 | 68.159 | 93.014 |
| 3.15 | 25.740 | 7.770 | 53.57 | 2.4 | 3.045 | 3.35 | .11274 | 21.287 | 27.005 | 29.714 |
| 3.53 | 20.305 | 6.732 | 41.84 | 1.33 | 2.335 | 3.05 | .11068 | 12.197 | 21.096 | 27.586 |
| 1.53 | 51.832 | 6.229 | 104.66 | 1.33 | 3.112 | 4.48 | .13860 | 9.595 | 22.455 | 32.32 |
| 4.61 | 46.680 | 15.674 | 81.38 | 2.58 | 4.207 | 5.1 | .07385 | 34.935 | 56.960 | 69.058 |
| 2.16 | 40.760 | 7.100 | 61.24 | .7 | 2.121 | 3.5 | .08070 | 8.67 | 26.280 | 43.37 |
| 4.51 | 55.390 | 11.305 | 110.26 | 2.8 | 4.517 | 6.7 | .12323 | 22.72 | 36.650 | 54.36 |
| 1.128 | 23.356 | 3.007 | 43.58 | .3 | 1.077 | 2.25 | .06308 | 4.755 | 17.073 | 35.669 |
| 7.634 | 131.920 | 19.264 | 257.12 | 2.6 | 3.136 | 5.08 | .06275 | 41.43 | 49.976 | 80.956 |
| 6.38 | 33.470 | 11.070 | 69.18 | 1.6 | 3.758 | 9.2 | .14274 | 11.209 | 26.327 | 64.45 |
| 4.74 | 27.708 | 9.212 | 81.75 | 1.78 | 2.168 | 2.12 | .06618 | 26.89 | 31.530 | 32.03 |
| 1.26 | 71.755 | 6.508 | 127.53 | .9 | 1.76 | 1.22 | .07295 | 12.337 | 24.127 | 16.72 |
| 3.29 | 78.970 | 9.515 | 138.31 | .81 | 2.399 | 3.58 | .04033 | 20.084 | 59.484 | 88.83 |
| 1.686 | 75.750 | 7.52 | 145.23 | 1.8 | 3.284 | 4.07 | .11415 | 15.768 | 28.769 | 35.65 |
| 1.339 | 59.558 | 5.738 | 144.39 | 1.05 | 3.380 | 5.4 | .06856 | 15.315 | 49.299 | 78.76 |
| 2.392 | 50.919 | 6.312 | 99.08 | 1.9 | 2.640 | 3.65 | .09415 | 20.18 | 28.104 | 38.76 |
| 2.97 | 46.910 | 7.672 | 114.91 | 1.58 | 4.17 | 7.95 | .14669 | 10.77 | 28.427 | 54.145 |
| 4.36 | 34.133 | 9.059 | 94.58 | .51 | .816 | 1.05 | .06956 | 7 33 | 11.74 | 15.094 |
| 2.799 | 16.670 | 5.029 | 37.17 | 1.4 | 2.408 | 3.8 | .09895 | 14.148 | 24.33 | 38.40 |
| 4.74 | 27.708 | 9.212 | 81.75 | 1.78 | 2.168 | 2.12 | .06618 | 26.89 | 32.754 | 32.03 |
| 2.35 | 62.121 | 8.390 | 93.404 | 2.9 | 4.350 | 6.15 | .12892 | 22.49 | 33.750 | 47.79 |
| 3.328 | 49.540 | 11.680 | 126.78 | 1.05 | 2.297 | 3.64 | .06689 | 15.69 | 34.340 | 54.40 |
| 3.909 | 66.579 | 17.093 | 130.306 | 4.35 | 5.363 | 6.65 | .18227 | 23.865 | 29.420 | 36.484 |
| 4.023 | 31.402 | 6.341 | 55.56 | .19 | .581 | .93 | .02840 | 6.69 | 20.471 | 32.746 |
| 7.81 | 75.520 | 14.159 | 117.17 | 4.45 | 7.880 | 11.07 | .15056 | 9.423 | 52.335 | 73.505 |
| 3.13 | 55.760 | 6.26 | 113.43 | 1.3 | 3.440 | 4.95 | .05030 | 25.785 | 68.389 | 98.409 |
| 1.541 | 43.931 | 5.553 | 94.824 | .7 | 1.990 | 3.08 | .10464 | 6.689 | 19.017 | 29.434 |

tions I have given this average loss for the day and night separately, and have added the extremes observed in order to show how widely the transpiration may vary in the same plant. In the plant under standard conditions similar results are given, though for day only.

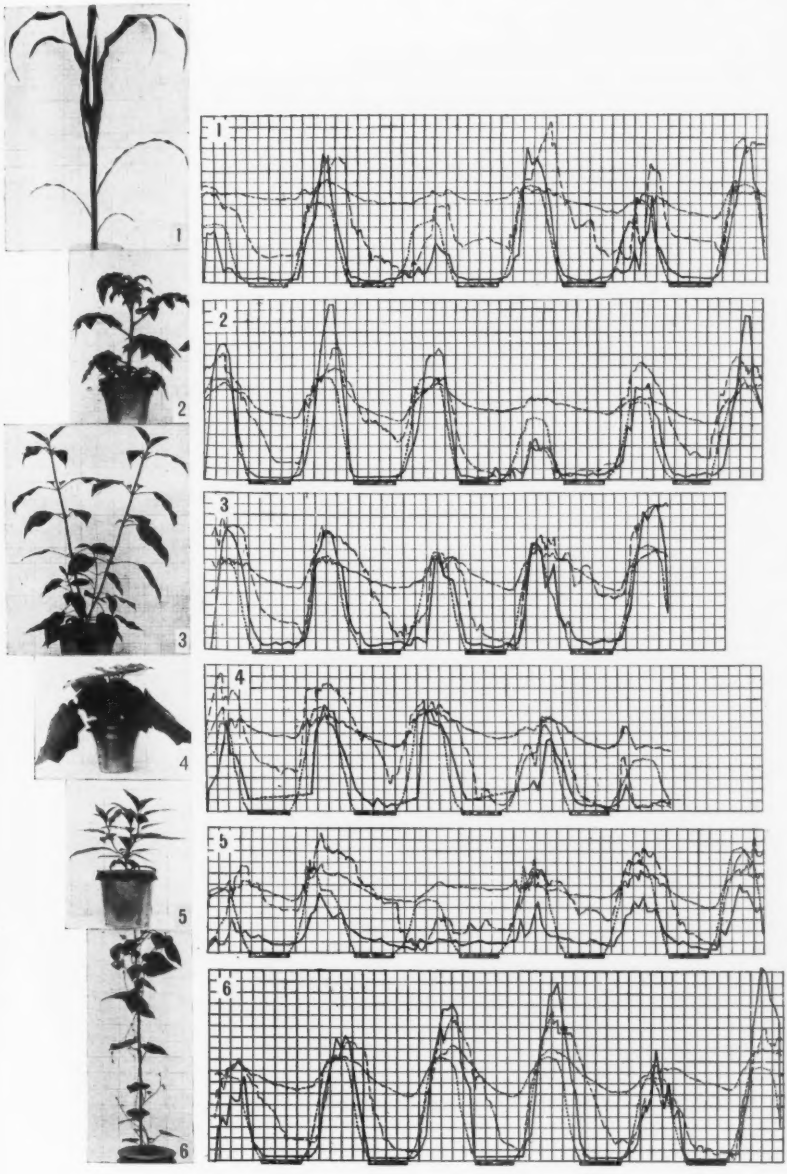
A comparison of the $M^2HG$ figures for the ordinary and standard conditions of the same plant will reveal some remarkable discrepancies. Thus, Helianthus under the ordinary conditions stands far ahead of any other plants studied, but under the standard conditions it is surpassed by several. The explanation of such differences is evident. The week in which the experiment was tried may have been one of exceptional dryness and brightness, or one in which air currents from ventilation, or perhaps greater heat, increased the transpiration of the plant under ordinary conditions but could not materially affect that under standard conditions. It is evident therefore that for comparison of the transpiration of one plant with another the columns under ordinary conditions have little value, and for this the column under standard conditions should be used. It is in order to exhibit clearly the effects of such external conditions upon transpiration that I have plotted for the same plants the transpiration in graphs, along with the graphs of external conditions, in the series of diagrams which follow below. Another peculiarity of the tables is found in the great range in the same plant under standard conditions. This comes in part from the difficulty of keeping the conditions constant, in part from the great sensitiveness of the process to even slight alterations of external conditions, but chiefly from the variations in light. Absolute proof of this could only be obtained from a series of careful experiments where all factors would be under control and only one varied at a time. It can reasonably be inferred, however, on this ground: on bright sunny days there was a gradual increase and decrease proportional to the light intensity. On cloudy days or when the roof was covered with snow, with the curtain aside, the loss per hour varied within much narrower limits. Comparison of the losses at the same hours on different days also justifies this conclusion.

It will occur to the reader at this point that not enough plants of each species were used to give results which are fair tests of the transpiration of a given species. This criticism is only in part just. It is obviously impracticable to provide either the excessive time or the

numerous instruments requisite for obtaining averages from several plants. Aside from this, however, the results are more representative than may appear at first sight. On the one hand the plants were carefully chosen from a considerable number as typical specimens of their kinds, and on the other, according to QUÉTELET'S law, any single plant taken at random is more likely to fall close to the mean than far from it. Hence, taking our thirty plants collectively, while some of them may deviate considerably from the mean of their kind, the great majority must lie more or less close to it.

Although the table of figures expressing the total quantities of transpiration has its value, it cannot be made to throw light upon the effect of external conditions upon transpiration. In consequence graphs made of each plant under *greenhouse conditions* were plotted from the records of the autographic instruments. In all cases they are for six days, the day and night being indicated on the base line. Each abscissa space represents $2\frac{1}{2}$ hours of time; each ordinate space in the transpiration curve equals either 1, $\frac{1}{2}$, or 2 grams of water lost, as indicated in each case, the difference being necessary to bring the curves of the plants within practical ranges; one vertical space in the temperature curve represents 5°; in the curve of moisture, 1 per cent. of saturation; and in that of light, 5, 2.5, or 10 per cent. of intensity. The curve of moisture has been inverted into one of dryness so that all physical conditions tending to increase transpiration have upward turns, and *vice versa*. The curve of light shows the intensities available to the plant, not what the plant actually used; this varies with the structure and the internal physiological processes.

As indicated above, these graphs have two values. The first is to show under what external conditions the figures for ordinary conditions given in the table were obtained. It is obvious that these values are profoundly affected by the conditions prevailing when the experiment was in progress. The second value is to present as clearly and graphically as possible the relations of the rate of transpiration to external conditions. It is not supposed that these graphs can bring out any knowledge of transpiration new in the abstract, but they do show this relation with gratifying clearness for our most familiar plants, and in a form which, it is hoped, will make them valuable in educational work.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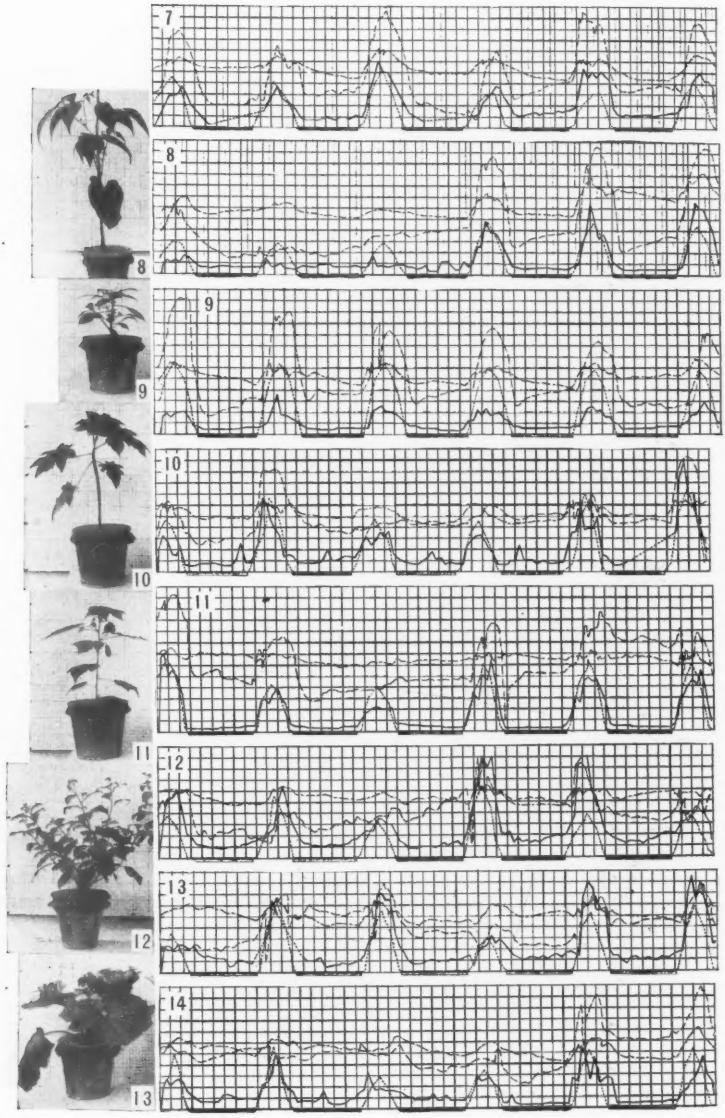
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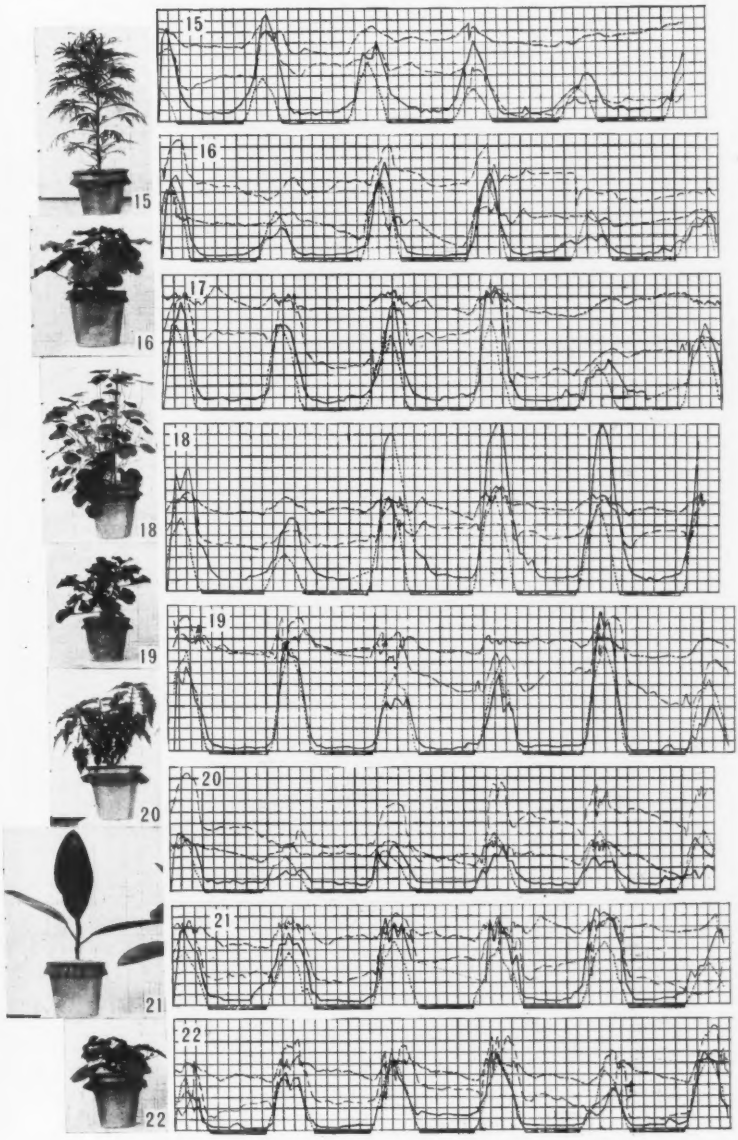
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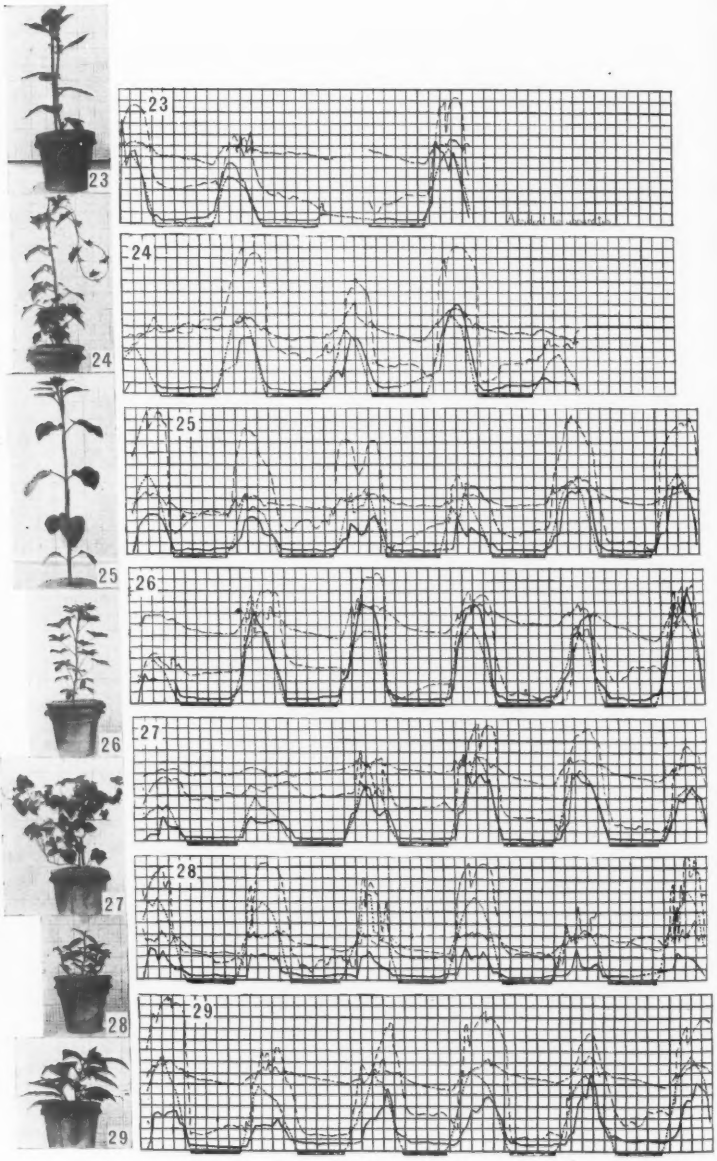
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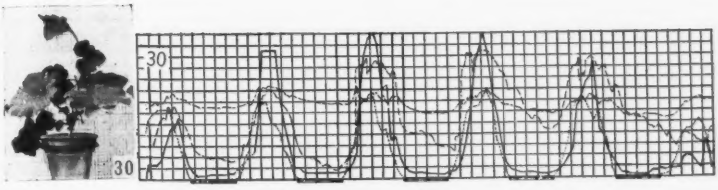


EXPLANATION OF GRAPHS

T=temperature — · · — · · —  D=dryness — — — —
L=light · · · · · · · · ·  Tr=transpiration————————

The values given for *T* should be read in the seventh vertical space from the base line; *D* in the fifth; *L* in the third; and *Tr* in the first.

1. *Zea Mays.* May 7–12. T 10–15; D 30–35; L 20–30; Tr 0–1.
2. *Lycopersicum esculentum.* May 13–18. T 15–20; D 30–35; L 20–30; Tr 0–1.
3. *Salvia involucrata.* May 20–25. T 10–15; D 35–40; L 20–30; Tr 0–1.
4. *Senecio Petasitis.* May 28—June 2. T 10–15; D 35–40; L 20–30; Tr 0–2.
5. *Cestrum elegans.* June 3–8. T 20–25; D 35–40; L 20–30; Tr 0–½.
6. *Ipomoea purpurea.* June 10–15. T 10–15; D 30–35; L 20–30; Tr 0–½.
7. *Euphorbia pulcherrima.* Oct. 22–27. T 20–25; D 30–35; L 20–30; Tr 0–1.
8. *Phaseolus vulgaris.* Oct. 29—Nov. 3. T 15–20; D 40–45; L 20–30; Tr 0–1.
9. *Impatiens Holstii.* Nov. 5–10. T 20–25; D 40–45; L 10–15; Tr 0–½.
10. *Ricinus communis.* Nov. 12–17. T 20–25; D 40–45; L 10–15; Tr 0–½.
11. *Abutilon striatum.* Nov. 19–24. T 15–20; D 30–35; L 10–15; Tr 0–½.
12. *Heliotropium peruvianum.* Nov. 26–31. T 20–25; D 40–45; L 10–15; Tr 0–1.
13. *Cineraria stellata.* Dec. 6–12. T 20–25; D 50–55; L 10–15; Tr 0–1.
14. *Primula sinensis.* Dec. 13–19. T 20–25; D 40–45; L 10–15; Tr 0–½.
15. *Chrysanthemum frutescens.* Jan. 14–19. T 10–15; D 50–55; L 10–15; Tr 0–2.
16. *Pelargonium zonale.* Jan. 21–26. T 30–35; D 40–45; L 10–15; Tr 0–2.
17. *Fuchsia speciosa.* Jan. 28—Feb. 2. T 0–5; D 40–45; L 10–15; Tr 0–1.
18. *Tropaeolum majus.* Feb. 4–9. T 10–15; D 45–50; L 10–15; Tr 0–1.
19. *Pelargonium domesticum.* Feb. 11–16. T 0–5; D 30–35; L 10–15; Tr 0–1.
20. *Coleus Blumei* var. Feb. 18–23. T 50–55; D 20–25; L 20–30; Tr 0–1.
21. *Ficus elastica.* Feb. 25—Mar. 2. T 15–20; D 55–60; L 20–30; Tr 0–½.
22. *Pelargonium peltatum.* Mar. 4–9. T 20–25; D 50–55; L 20–30; Tr 0–1.
23. *Vicia Faba.* Mar. 11–20. T 15–20; D 40–45; L 20–30; Tr 0–½.
24. *Senecio mikanioides.* Mar. 18–23. T 20–25; D 30–35; L 10–15; Tr 0–1.
25. *Helianthus annuus.* Mar. 25–30. T 25–30; D 35–40; L 20–30; Tr 0–2.
26. *Lupinus albus.* Apr. 1–6. T 10–15; D 40–45; L 20–30; Tr 0–½.
27. *Hedera Helix.* Apr. 8–13. T 15–20; D 40–45; L 20–30; Tr 0–½.
28. *Tradescantia zebrina.* Apr. 15–20. T 30–35; D 40–45; L 20–30; Tr 0–½.
29. *Begonia argentea guttata.* Apr. 22–27. T 30–35; 15–20; DL 20–30; Tr 0–½.
30. *Cucurbita Pepo.* Apr. 29—May 4. T 15–20; D 30–35; L 20–30; Tr 0–1.

Briefly they bring out these facts: there are two daily extremes, a maximum loss around noon when the sunlight is most intense, heat usually the greatest, moisture least in the atmosphere, but a good supply of water in the soil around the roots; the minimum loss occurs some time during the night when the temperature is low, the atmospheric moisture approaches saturation, the darkness is complete, and in most plants the stomata are closed. The curve from 8 to 9 in the morning sometimes suddenly drops or rises. This is due either to the

time lost when the plant is watered and rebalanced or to the falling of sunshine directly upon the plant. The drop in the curves between February and March 18 just after noon is due to the shading of the plant from the direct afternoon sun by an intervening house.

The effects of cool, cloudy, moist days are well brought out in the curve of *Phaseolus vulgaris*, where such conditions prevailed the first half of the week, tending to check transpiration; while the brighter, warmer, drier, latter half of the week increased the loss of water. The same differences are seen equally well in the curves of *Pelargonium domesticum* and *P. peltatum*, Fuchsia, and Tropaeolum; and are more strikingly shown in those of *Senecio mikanioides*, *Lupinus albus*, *Zea Mays*, *Senecio Petasitis*, *Cucurbita Pepo*, *Lycopersicum esculentum*, and *Abutilon striatum;* but the last-named plant and Chrysanthemum were at no time in brilliant sunlight.

In general the transpiration curve supplements the tabulated results, showing in addition the effects of physical conditions. The important fact brought out by the curves as a whole is the extreme sensitiveness of transpiration to even slight changes in external conditions, a fact already mentioned above in connection with the variations shown under "standard" conditions. So great, indeed, is this sensitiveness that it seems out of all proportion to the direct physical changes and suggests the possibility that the relation between conditions and transpiration is not purely physical, as it is apparently now considered by some students, but is indeed one which involves the action of the conditions as stimuli. But this is a separate matter and I have been concerned merely with transpiration as a fact, quite regardless of its explanation. Furthermore, I have not tried to separate the influence of the conditions nor to show, when several cooperate, which produces the greatest effect. I have taken them as they came; their separation is a separate investigation.

We consider now the results of this study from the practical point of view of the teacher, as to which plants are best for the demonstration of transpiration. While the columns designated "$M^2HG$ average" give some plants a greater average transpiration, the columns of "$M^2HG$ minimum and maximum" really offer a better choice of material, because they show the great range possible for each plant. *Helianthus annuus* stands first in amount of transpiration, but it is open

to objection in that it is not kept in greenhouses and must be grown expressly several weeks before needed for use in the classroom. *Vicia Faba, Lupinus albus, Lycopersicum esculentum, Ipomoea purpurea,* and *Cucurbita Pepo,* although they show a high rate of transpiration, are open to the same objection. The first choice falls, then, in order of respective excellence to *Chrysanthemum frutescens, Tropaeolum majus, Pelargonium domesticum, Fuchsia speciosa, Senecio Petasitis, Senecio mikanioides, Pelargonium zonale, Heliotropium peruvianum,* and *Pelargonium peltatum.* They are best for two reasons: their first value lies in the fact that they lose large amounts of water; the second, and no less important, is that in addition to their being easily obtained at any time of year from the greenhouse, they are grown in many homes. An objection to *Euphorbia pulcherrima* and *Impatiens Holstii,* moderate transpirers, is that they lose many leaves just at maturity; this is true also of the heliotrope. Of least value are *Primula sinensis, Coleus Blumei, Hedera Helix, Cestrum elegans, Begonia argentea,* and *Tradescantia zebrina,* which, though common, have a very low rate of transpiration.

In addition to the value given by the tables for the different kinds of plants, it will be of some interest to note the average transpiration for these plants taken collectively. The result may be considered a general expression of the amount of transpiration of ordinary plants growing in any greenhouse. This quantity is 48.732 or in round numbers about 50 grams per hour per square meter of surface for the day time, and 8.898, or in round numbers 10 grams for the night—about five times as much on the average per hour per square meter by day as by night.

NORTHAMPTON, MASS.

# BRIEFER ARTICLES

## LUCIEN MARCUS UNDERWOOD

(WITH PORTRAIT)

The editors of the BOTANICAL GAZETTE wish to make this brief record of the life and work of a distinguished American botanist and an intimate personal friend. The papers prepared for the memorial meeting of the Torrey Botanical Club, held January 29, 1908, have been published in the *Bulletin* of that club (**35**: 1–43. 1908), so that a full account is not necessary here.

Professor UNDERWOOD was born October 26, 1853, at New Woodstock, N. Y., and died at Redding, Conn., November 16, 1907. He graduated at Syracuse University in 1877, and held the following college and university positions: Hedding College (1880), Illinois Wesleyan University (1880–1883), Syracuse University (1883–1890), De Pauw University (1890–1895), Alabama Polytechnic Institute (1895–1896), Columbia University (1896–1907).

His chief work was with the Pteridophytes, and the repeated editions of *Our native ferns* bore testimony to his early activity and to the popularity of the book. This work laid the foundation for the larger and more serious interest in the group which bore abundant fruit in his maturer years. The Hepaticae were also included in the range of his professional interest; and the Fungi also shared in his contributions. His bibliography, as published in the memorial proceedings referred to, includes 212 titles, 188 of which are botanical; and among these 78 deal with Pteridophytes, 31 with Hepaticae, and 29 with Fungi.

Great as is the loss to American botany, the personal loss will be felt still more keenly by his colleagues. He was eminently a companionable

man, and at every botanical gathering which included him he was a center of sprightly conversation and good feeling. These qualities, and his untiring and unselfish devotion to his work and to his students, developed for him an amount of personal affection and loyalty that was his chief possession. His place in American botany was sufficiently unique to remain vacant; and his personality will be still more impossible to duplicate.

## A CONVENIENT TRAVELING BALANCE

(WITH TWO FIGURES)

In carrying out certain lines of investigation involving more or less travel, or the establishment of temporary stations remote from well-equipped laboratories, the lack of a compact and readily transportable balance, of a fair degree of sensitiveness, often seriously hampers the progress of the

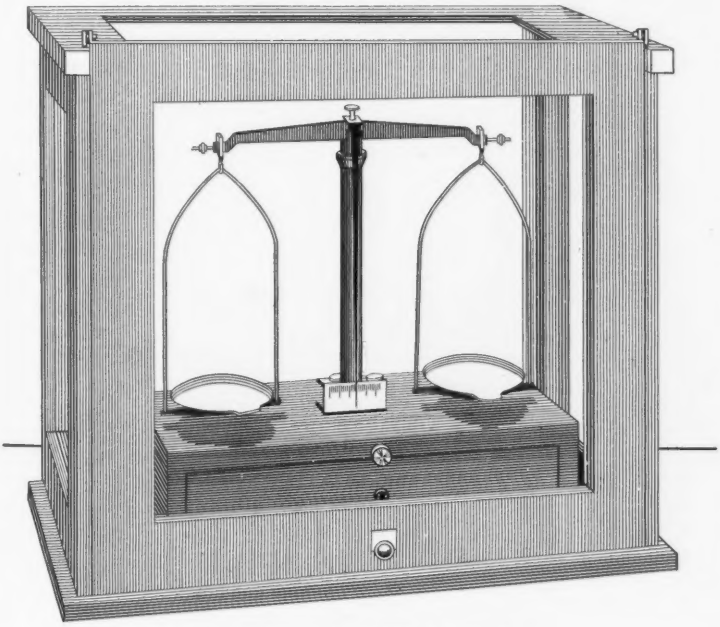

FIG. 1.— Balance set up within the closed case.

work. The ordinary balance inclosed in its glass case is too cumbrous and fragile to be readily transported, yet no dependable weighing can be made except upon a suitable balance properly protected.

In preparing an outfit of apparatus for field use I have devised a convenient form of "knock-down" balance with collapsible case, which in great measure solves the question of a practicable field balance.

The balance proper and the case are entirely independent. From a reliable instrument maker I ordered a good type of laboratory balance fitted with the usual accessories but without the glass case. The pillar is fastened to the box with screws having milled heads and is readily removable. All the metal parts of the balance can be detached and packed safely in the drawer of the box.

The case for this balance is made in six sections, of which those forming

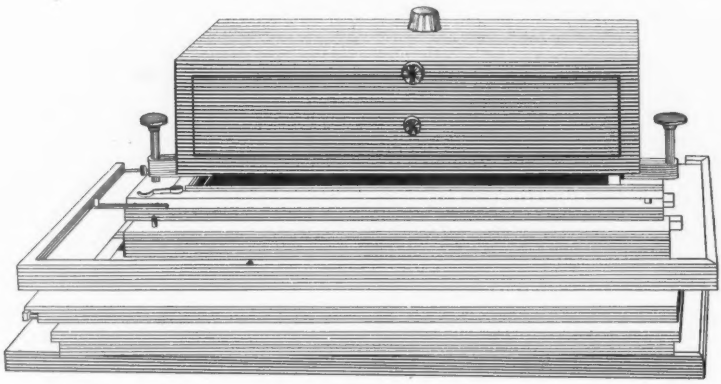

FIG. 2.—Case collapsed and balance packed.

the ends are secured in place on the base by dowel pins. The joints of the case are made dust proof by means of a tongue-and-groove fitting. The door is hinged at the upper corners by means of pivot hinges and swings outward. After all the sections are in place, complete stability is secured by means of small hooks and screw-eyes which lock the various parts together. Instead of glass, clear celluloid is used, which renders the case practically non-breakable.

*Fig. 1* shows the balance set up within the case which is closed; *fig. 2* shows the case collapsed and balance packed. The total weight of balance and case is approximately ten pounds, and in the collapsed form may readily be carried in a trunk or even in a suit case.—W. W. STOCKBERGER, *Bureau of Plant Industry, Washington, D. C.*

## THE TOXIC ACTION OF CERTAIN ORGANIC PLANT CONSTITUENTS.—A CORRECTION

THE EDITORS regret that in the article by SCHREINER and REED in the February number of this journal, vol. 45, pages 80 and 90, *figures 2* and *6*, illustrating the action of cholin and of cumarin, were interchanged. All of the figures appear without legends. These have now been supplied by the authors and are as follows:

FIG. 1.—Wheat grown in: (1) Freshly prepared solution of tyrosin, 16 parts per million; (2) discolored solution of tyrosin, originally containing 16 parts per million.

FIG. 2.—(Applies to block printed as *fig. 6*, p. 90.) Wheat grown in: (1) Control in pure distilled water; (2) solution of cholin, 1000 parts per million; (3) 500 parts; (4) 100 parts; (5) 25 parts; (6) 5 parts; (7) 1 part.

FIG. 3.—Wheat grown in: (1) Solution of pyrocatechin, 1000 parts per million; (2) 500 parts; (3) 100 parts; (4) 25 parts; (5) 1 part; (6) control in pure distilled water.

FIG. 4.—Wheat grown in: (1) Solution of phenol, 250 parts per million; (2) resorcin, 250 parts; (3) phloroglucin, 250 parts; (4) phenol, 100 parts; (5) resorcin, 100 parts; (6) phloroglucin, 100 parts.

FIG. 5.—Wheat grown in: (1) Solution of vanillin, 1000 parts per million; (2) 500 parts; (3) 100 parts; (4) 25 parts; (5) 1 part; (6) control in pure distilled water.

FIG 6.—(Applies to block printed as *fig. 2*, p. 80.) Wheat grown in: (1) Control in pure distilled water; (2) solution of cumarin, 1 part per million; (3) 25 parts; (4) 50 parts.

FIG. 7.—Wheat grown in: (1) Solution of esculin, 1000 parts per million; (2) 500 parts; (3) 100 parts; (4) 25 parts; (5) 1 part; (6) control in pure distilled water.

# CURRENT LITERATURE

## BOOK REVIEWS

### Chemistry of the higher fungi

Investigations on the chemistry of fungi began about a century ago, and have been prosecuted with various aims. Sometimes the endeavor has been to isolate unknown substances, and especially poisonous or medicinal ones; sometimes to ascertain the nutritive value of edible species; and sometimes to contribute to the general knowledge of this group. Though the separate studies have been numerous, hardly more than a beginning has yet been made, as shown by the fact that out of the immense number of species, the chemistry of only four is known with even approximate completeness.

ZELLNER, who himself has contributed much to the subject, has collated the present data in a monograph of some 250 pages.[1] He excludes from his consideration, by the adjective "higher," the bacteria, molds, and yeasts, recognizing that this is nothing more than a convenient discrimination. The matter is not arranged by species or groups of fungi, but by groups of substances, such as mineral constituents, fats, alcohols, amino-acids, tannins, coloring matters, toxins, etc. The largest sections are those which treat of fats, bases, carbohydrates, and enzymes. To compensate for the disadvantages of this mode of presentation, the author furnishes a complete index of the names of species mentioned, which unfortunately he has separated from the index of substances mentioned. While an index is a good thing, two are never better than one.

In the way of generalizations the author gathers together, at the close of his volume, the information in regard to the four species, whose composition has been fairly determined. It may be interesting to know that these are *Amanita muscaria* L., *Polyporus officinalis* Fr., *Claviceps purpurea* Tul., and *Aethalium septicum* L. He also attempts to distinguish by their chemical characteristics the following groups, whose composition is dependent upon the substratum: (1) saprophytes (living in humus), (2) coprophytes, (3) wood dwellers, partly saprophytic, partly parasitic, (4) plant parasites, (5) animal parasites.

Regarding the higher fungi as a whole, ZELLNER notes these chemical peculiarities: the cell membrane consists chiefly of chitin, or an allied substance, fungin, true cellulose and true wood material never having been found in fungi; they likewise contain no starch, but dextrin-like carbohydrates or glycogen are widely distributed, though in variable amounts; the fats are mostly rich in free fatty acids, associated with bodies of the ergosterin group and mostly also lecithins; basic

[1] ZELLNER, J., Chemie der höheren Pilze. 8vo. pp. vi + 257. Leipzig: Wilhelm Engelmann. 1907. *M* 9.

bodies, allied to trimethylamin, are widely distributed, but no true alkaloid has yet been found. The composition of fungi and animals shows some striking resemblances.

In gathering together the data regarding the chemistry of the higher fungi, in citing the literature, and in describing methods of isolation and identification, ZELLNER supplements acceptably the related sections of CZAPEK's *Biochemie der Pflanzen* and facilitates further studies in this field.—C. R. B.

### "Sleep" movements

In a monograph of some two hundred pages PFEFFER[2] describes his recent investigations on the so-called "sleep" movements of leaves. For these researches he has planned ingenious methods of securing the self-registration of the movements of simple leaves, or the folding of a number of leaflets. In addition to the clever arrangements of levers, he has devised several forms of registering apparatus, and methods for continuous and intermittent illumination, in which the disturbing effects of varying temperature are eliminated, and at will a sudden or gradual illumination is secured, by electric tungsten or mercury lamps, without sparking at the contacts. These methods and apparatus will doubtless prove of very great service, not only in the study of "sleep" movements, but also wherever, as in this case, optical methods of record are not suitable.

The records published in this monograph, giving for the first time the autographs of leaves subjected to varying conditions of light and temperature, are likely to become classic illustrations. They show not only the so-called "sleep" movements, but also the independent autonomous movements which often accompany them, and the interesting rhythmic movements that persist for some time when the leaves are kept in uniform conditions. The work is one which will take its place with other monographs of this author as a permanent contribution to plant physiology. The contribution, however, lies rather in the useful apparatus and in the direct results recorded than in any theoretical considerations which are deducible.

The "sleep" movements, whether they are executed by growth or turgor, are herein definitely shown to be photonastic or thermonastic reactions, called forth by the daily change of illumination or temperature, or by the co-operation of both factors. That being the case it is to be regretted that the author does not adopt some more suitable term than the misleading *Schlafbewegungen*. When under constant conditions the "sleep" movements gradually disappear in 3–5 days through after-movements of diminishing amplitude, there often remain autonomous movements of much shorter rhythm, which are quite independent of the others. Many specific peculiarities in the responses are described, which cannot be here enumerated. Thermonastic responses show similar peculiarities and the photonastic reactions seem bound up, to a certain extent, with them, since in most leaves thermonastic responses may be induced when the photonastic ones have

[2] PFEFFER, W., Untersuchungen über die Enstehung der Schlafbewegungen der Blattorgane. Abhl. Math.-phys. Kl. König. Sächs. Gesells. Wiss. **30**:259–472. *figs. 36*. 1907. Separately of B. G. Teubner, Leipzig. *M* 8.

been excluded, and *vice versa*. The natural rhythm of response may be increased or diminished, provided the latent period of the organ is less than the daily period of light and darkness.

This work is one that will be needed in every active laboratory, so that any more detailed statements of its conclusions would be superfluous.—C. R. B.

## NOTES FOR STUDENTS

**Plant breeding.**—Bulletins of the various Agricultural Experiment Stations usually deal with the practical side of agricultural problems, and there has not been at all times a recognition of the practical value of theoretical matters emanating from pure scientific sources.

One can only commend the purpose of Dr. E. M. EAST[3] in issuing a bulletin in which a well-written review of the development of the evolution idea is given, along with the more recent developments in our knowledge of variations and of heredity. In the main the treatment is well balanced, but in some respects there is too obvious a leaning on MORGAN'S recent publications. Particularly does it seem out of place, in so brief a paper, to present MORGAN'S theory of the impurity of the gametes—a theory which has lost practically all the slight support it seemed to have when first propounded.

It is noted on p. 68 in the discussion of the Belgian-hare cross, as an illustration of "masked" characters, that the older explanation is retained, based upon the supposed presence of a black factor in the albino. CASTLE[4] has given a more satisfactory explanation of such cases by assuming an "agouti factor" which distributes the pigment in distinct regions in each hair, giving a grey effect. The Belgian hare of the experiment cited had both dominant characters, namely pigment and agouti, and the albino lacks them both. The advantage of CASTLE'S explanation lies in the fact that it brings such cases into harmony with the "presence and absence" hypothesis which has found such wide support in other cases and to which the author of the bulletin himself subscribes.

The section on "Methods of plant improvement" is doubtless the most valuable part of the paper. Its scope may be indicated by the subheads: "The selection of fluctuations," "Isolation of elementary species," "Judging plants by their progeny," "Correlated characters," "Improvement by hybridization." Under the first of these subheads a valuable summary is given of the results gained by HOPKINS and his associates at the Illinois Experiment Station in the breeding of maize for high and low protein and high and low oil content. The crop averages for ten years are given, showing that in this time the maximum separation of the extremes with respect to these characters seems to have been attained.

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[3] EAST, E. M., The relation of certain biological principles to plant breeding. Conn. Agric. Exp. Sta., Bull. 158. pp. 93. *figs.* 6. 1907.

[4] CASTLE, W. E., On a case of reversion induced by cross breeding and its fixation. Science N. S. **25**:151–153. 1907.

On p. 62 the "Knight-Darwin law" that "nature abhors perpetual self-fertilization" is amended to read, "nature resists any sudden change in long-established conditions." A suggestion having the same import was made some years ago by HAYS,[5] but this seems to have been overlooked by Dr. EAST. HAYS says, "possibly DARWIN's law would more broadly cover the truth if expressed thus: nature abhors a radical change which would require species to cross in much closer or in much more radical relationship than is their long-established habit."

The last ten pages preceding the summary discuss the technique of maize breeding, giving an insight into the great complexity of the problems to be solved in breeding this crop, owing to the occurrence of fluctuations and numerous elementary species, and the injurious effects of too close inbreeding. The author's experience in maize breeding, as an associate of HOPKINS at the Illinois Station, and his continued efforts along similar lines at the Connecticut Station, have thoroughly qualified him to write on this subject, and his discussion will doubtless prove of great value to maize breeders; but the reviewer questions the correctness of the assumption that the isolation of pure strains of maize is the proper aim of those who would secure the greatest possible improvement in this crop.

It is believed that this excellent bulletin will have such a reception that other stations will follow Dr. EAST's example in disseminating advanced scientific information.—G. H. SHULL.

**The latent life of seeds.**—Two rival doctrines have been used heretofore, with equal success, to account for the latent life of seeds. The one holds that life is completely suspended, all the exchanges, both of matter and of energy, being arrested. The other holds that the phenomena of metabolism are greatly diminished, but that they are never entirely suppressed. Both of these theories have been supported by experimental evidence, and the question has called forth a very large number of investigations. These antagonistic views have led BECQUEREL to a further study,[6] with the idea that the previous conflicting results depended upon neglected properties of the integuments. He has demonstrated the impermeability for gases of the integuments of seeds of a considerable number of species; and it seems GOLA[7] simultaneously had discovered impermeability for water to be a common character.

These facts make it necessary to go over previous experiments, perforating the integuments or removing them. Seeds which resist the action of alcohol, ether, and chloroform, when their integuments are intact, succumb when these agents are brought into actual contact with the embryo. But low temperatures, even to $-210°$, do not have any appreciable effect on germination if the protoplasm has already undergone thorough desiccation. The existence of gaseous exchanges,

[5] HAYS, W. M., Plant breeding. U. S. Division of Physiology and Pathology, Bull. No. 29. pp. 72. *figs. 21.* 1901. (See pp. 38, 39.)

[6] BECQUEREL, PAUL, Recherches sur la vie latente de graines. Ann. Sci. Nat. Bot. IX. **5**:193–320. 1907.

[7] As cited by BECQUEREL: GOLA, J., Mémoire sur la physiologie [in another place, Recherches sur] des téguments des graines. Acad. [Sci.] Turin. 1905.

heretofore attributed to respiration, was confirmed. But it is clearly shown that the fixation of oxygen and the evolution of $CO_2$ have no relation to the life of the seed, and that a direct oxidation probably takes place with equal activity in live and dead seeds. Thus the gaseous exchanges of the integuments, compared with those of the decorticated seeds from which theycame, were frequently, weight for weight, very much larger. Further, these exchanges in the isolated integuments, compared with those of the entire seeds of the same species whose integuments are impermeable, are absolutely the same. Where the integument is permeable, however, the gaseous exchanges of the embryo are added to those of the integuments. None of these changes take place unless the air is moist and the protoplasm contains still a certain proportion of water.

BECQUEREL has also shown that no perceptible gaseous exchanges take place in the embryo when completely dehydrated, and that it can bear for a long time an atmosphere of carbonic acid, nitrogen, or a complete vacuum without losing its power to germinate. In fact, he is convinced that the loss of germinative power is dependent upon the changes permitted by the hygroscopicity of the seeds, and the only ones in which longevity is to be looked for are those with an impermeable integument.

Incidentally he discusses the longevity of seeds *in extenso*, and himself made experiments upon almost 500 species, belonging to 30 of the most important families of monocots and dicots, whose age was accurately known from the records of the *Muséum d'Histoire Naturelle* of Paris. Only four families had any viable seeds. Eighteen species of Leguminosae (87 to 28 years old), three species of Nelumbium (56 to 18 years), one Lavatera (64 years), and a Stachys (77 years) germinated.

BECQUEREL seems to have reduced the question to this dilemma: since there is no appreciable metabolism for as much as two years' time, in perfectly dry yet viable seeds, either their life-processes are wholly anaerobic, intracellular, and very slow, or life is completely suspended. He has begun an experiment of ten years' duration to determine whether the dried protoplasm is stable in a vacuum as perfect as can be obtained. He has inclosed in exhausted vials dry seeds of buckwheat and of wheat, with perforated integuments. These vials will be kept in darkness and will be examined with a spectroscope for gases every year, and at the end of ten years the seeds will be planted. This experiment promises to be a crucial one, if (as is to be expected) no gases are set free, and the seeds live. If it turns out otherwise, the choice between retarded life or suspended life for seeds will remain a speculative one.—C. R. B.

**Apogamy and apospory in ferns.**—HELENE WORONIN,[8] working in GOEBEL'S laboratory, has published the results of an experimental study on apogamy and apospory in ferns. The study included six species; *Trichomanes Kraussii*, *Pellaea flavens*, *P. nivea*, *P. tenera*, *Notochlaena Eckloniana*, and *N. sinuata*.

[8] WORONIN, HELENE, Apogamie und Aposporie bei einigen Farnen. Flora **98**: 101–162. *figs.* 72. 1907.

Three species of Cheilanthes (*tomentosa*, *persica*, and *fragrans*) and five species of Notochlaena (*Marantae*, *squamosa*, *trichomanoides*, *vellaea*, and *lanuginosa*) were studied to induce apospory and apogamy, but without success, excepting one case of *N. Marantae*, which she says is a very rare one.

The paper first gives a description of *Trichomanes Kraussii* as to its general morphology, structure and development of antheridia, apogamy, and apospory. Then there follows an account of apogamy and apospory in three forms of Pellaea (*flavens*, *nivea*, and *tenera*) and two species of Notochlaena (*Eckloniana* and *sinuata*). Next there is given the result of apogamous and aposporous development in *Pellaea flavens* under culture both in darkness and on sandy soil. Last there is an account of the result of experiments on regeneration, using the two apogamous species of Pellaea (*nivea* and *flavens*), one apogamous form of Notochlaena (*Eckloniana*), and two normal species (*Gymnogramme farinifera* and *N. Marantae*).

From the detailed account a few points of interest may be summarized as follows: The prothallia of *Trichomanes Kraussii* consist of both filamentous and flattened parts; archegonia fail to develop; antheridia never attain maturity, apogamous embryos develop from the filamentous part, or from the margin or surface of the flattened part; at the outset the apogamous embryo consists of several cell layers which the author thinks to be homologous with the archegoniophore; from this structure a leaf process first appears, and then the stem apex develops independently of the former; the appearance of the root is delayed. Apospory is also induced in the same species by cultivating cuttings of leaves on loam; often the aposporous tendency prevails so far that antheridia are formed directly from the margin of the leaf.

The three forms of Pellaea (*flavens*, *nivea*, and *tenera*) and two species of Notochlaena (*Eckloniana* and *sinuata*) are all apogamous. No archegonia ever develop, and in *N. sinuata* no antheridia are ever formed. Generally speaking, in these five forms the apogamous structure is formed first as a leaf on the under surface of the sinus of the prothallium from the apical meristem. The stem apex then appears quite independent of the leaf; either between the leaf and prothallium or under the leaf; the root appears later.

In *Pellaea flavens*, grown in darkness, there is induced an apogamous structure, at first appearing as a leaf. After continued cultivation in darkness apospory was induced; from the arrested leaf grown under the sinus of the prothallium a new prothallium is formed which bears antheridia and develops also apogamous structures. It was not possible to distinguish the boundaries of the prothallial and apogamous structures. In sand cultures of *Pellaea flavens* there were found leaf buds on the arrested leaf grown under the sinus of the prothallia. Apogamous structures also developed from the same prothallium.

As a result of regeneration there appeared several interesting cases. When cut fragments of the sinus region of prothallia are put on the soil, further continuous development is checked, but new structures arise. From these structures often prothallia are formed again. The prothallia aposporously produced develop antheridia.—S. YAMANOUCHI.

**Summation of light stimuli.**—It is well known that stimuli, too brief to produce a visible reaction, if repeated at intervals not too long, lead to a response, just as continuous stimulation for a sufficient time does. WIESNER found that when intermittent light stimuli followed each other within double the period of their duration, reaction began as soon as though the plants had been continuously stimulated. Generalizing from this he concluded that summation of the stimuli occurred without loss during the intervals. TALBOT's law, however, which holds with extreme exactness for the human eye, indicates that the effect of an intermittent light can only equal that of a constant one of lower intensity. Thus, if a light of intensity $i$ acts for $x$ seconds, at intervals of $3x$ seconds, its stimulating effect will be equal to that of a light of $i/4$ intensity. Obviously if this law be valid for heliotropic reactions of plants, reaction time, which alone WIESNER determined, cannot be a correct index of the effects of light as a stimulus. NATHANSOHN and PRINGSHEIM showed that this is so, and further undertook to make an extended comparison of the effects of constant and intermittent light stimuli.[8] Using such lights on opposite sides of seedlings of Brassica and Avena, they find that TALBOT's law is valid for heliotropic phenomena within reasonable limits. Only when the frequency and duration of the illumination was greatly reduced, as to $1\frac{1}{8}$ minutes duration with darkness $3\frac{3}{8}$ minutes, did the point of physiological indifference depart from the optical one (determined by the photometer) in favor of the intermittent light. Thus they established that there was, for plants as for the eye, a so-called critical periodicity. When intermittent stimuli are too slow, the eye sees a flickering; the plant responds by pendulum-like swings instead of a steady curvature. They also found the law valid within wider limits with weaker illumination than with strong.

In an elaborate theoretical discussion they propose to account for the observed phenomena of summation thus: They assume, with HELMHOLTZ, that the primary excitation is photochemical, and that its effect is proportional to the product of the intensity by the time of illumination. This produces a certain excitation, which is steadily maintained in constant illumination, but falls in the dark interval of intermittent illumination. In both cases a counter-reaction is assumed to be released, which antagonizes the primary reaction, and must be overcome if the latter is realized visibly. With constant illumination the algebraic sum of the light excitation and the counter-reaction determines the maximum effect. In intermittent light the counter-reaction is effective in the dark intervals in reducing the effect of each excitation, the remainder being added to by the next impulse, which serves at the same time to heighten the counter-excitation, and so on. As we understand it, the case for constant illumination might be represented thus: $a-b=c$, $a$ being the total direct excitation, $b$ the total counter-excitation, and $c$ the response, with intensity $i$. At the intensity $2i$, and alternate equal periods of light and darkness, the case is this: $(x-y)+[x-(y+k)]+n=c$; where $x$ is

[8] NATHANSOHN, A. und PRINGSHEIM, E., Ueber die Summation intermittierende Lichtreise. Jahrb. Wiss. Bot. **45**:137–190. 1907.

the direct excitation of each stimulus, $y$ the counter-excitation set up thereby, $k$ the increment of $y$, $n$ any number of additional terms, and $c$ the response. No good reason appears for assuming a counter-reaction. Partial or complete recovery from the primary excitation in the intervals of stimulation is a simpler assumption and would seem equally to account for the facts. Further details must be sought in the paper itself.—C. R. B.

**Edaphic steppes in Sweden.**—The "alfvar" is a name given in Sweden to some remarkable formations that occur chiefly on the island of Öland, and to a lesser degree on the island of Götland, and in the mainland province of Vestergötland. The name "alfvar" is applied to extensive treeless plains, whose underlying rock is a Silurian limestone. While there are several plant formations, the alfvar presents general ecological unity, and it has an extremely xerophytic stamp. It is somewhat similar to the "garigue" of southern Europe, and to certain rock formations of Servia. The physiognomy is that of a steppe, and yet there is anything but a steppe climate in Sweden. There is no question that the alfvar is determined by edaphic causes in the main (such as the dryness and temperature changes of the rocks, which are everywhere at or near the surface, and the poverty of the scanty soil), reinforced by strong insolation and constant winds. The alfvar is very distinct in every way from the heath. Such a region is relatively rich in species, of which more than half are glacial or subglacial, and about a third are representatives of the oak flora. Six per cent. belong to the climatic steppe, and only 2 per cent. to the beech forest flora. This flora is doubtless a relict of a much more widespread flora in the period succeeding glaciation. There are two general aspects, the dominant aspect of the steppe, and the lesser aspect of the meadow. The herbaceous plants commonly dominate, although shrubs are frequently conspicuous. The leading character plants of the steppe are *Mollia tortuosa*, *Helianthemum oelandicum*, and *Cynanchum vincetoxicum*. The chief shrubs are *Juniperus communis* and *Potentilla fruticosa*. In less xerophytic places, *Festuca ovina* assumes a prominent place. There are often vast areas of Cynanchum almost alone, giving almost an exact picture of certain climatic steppes. Perhaps the most interesting part of the paper is the discussion of nanism. The author distinguishes facultative dwarfs, due to environmental causes, and constitutional dwarfs. Constitutional dwarfs (the group to which the term nanism more properly applies) differ from facultative dwarfs not only in breeding true, regardless of conditions, but also in a much greater qualitative reduction. Constitutional dwarfs show reduction in all organs, not chiefly in aerial vegetative organs; roots and rhizomes are reduced, while they are rarely reduced and often actually increased in facultative dwarfs. Constitutional dwarfs also show reduced floral organs, their internodes are fewer as well as shorter, and their leaves are reduced in number as well as in size. Most of the dwarfs are annuals, although some show a certain lability as to their duration. Species commonly perennial or biennial, for example, may become annual in very dry situations. The usual "protective" structures of xerophytic vegetation occur

here in high degree, and are regarded by WITTE[10] as of advantage in checking transpiration. The alfvar was very fully treated from this standpoint some years ago by GREVILLIUS. Some plants commonly herbs here become half-shrubs, e. g., *Gypsophila fastigiata*. There is an excellent study made of the underground organs, which are frequently neglected.—H. C. COWLES.

**Lateral roots.**—NORDHAUSEN has studied the direction and growth of lateral roots under the influence of external factors, particularly those which arise from the removal of portions of the main root or its wounding.[11] It is well known that when a millimeter or less of the primary root is cut off, regeneration of the tip occurs; but when larger portions are removed, one or more of the lateral roots change their angle with the main axis, as it were to substitute themselves for it. NORDHAUSEN can only say, as one result of his studies, that this reaction on the part of the lateral roots is "dependent upon the intensity and quality of internal conditions which bear more or less relation to the needs of the plant," which of course is an empty form of words. It was already known that decapitation within the growth zone results in a very active substitution response. If the cutting exceeds this, however, whether much or little, says NORDHAUSEN, this response is minimal or wanting, provided a rather long piece of the primary root remains; but shortening the stump beyond a certain amount again increases the response. The alteration of the angle of the substitute roots with the main axis rests, contrary to the conclusions of BRUCK and CZAPEK, upon both geotropic and autotropic factors, of which the former is determinative. This substitution of lateral roots is independent of actual wounding, since it can be brought about by merely checking the growth, especially of the main axis. A partial response follows, even without disturbance or operation on the growing point, if certain tracts within the central cylinder (not only in the phloem but especially in the xylem) are interrupted by lateral wounding. The disturbance of nutrition here plays only a subordinate rôle. NORDHAUSEN agrees with MCCALLUM in assuming the existence of specific inhibitory stimuli, regulating the formation of organs in intact plants. Certain roots (Lupinus, Phaseolus) respond to a temporary past reduction in the water supply by altering the angle of lateral roots, which at the time of the difficulty had not even appeared, though when they develop they are under normal conditions. Lateral wounding of the main root leading to direct or indirect affection of the pericambium, even before the lateral roots become visible, produces a traumatropic deviation of these from the wounded side. The transmission of the excitation, easier in the acropetal than the basipetal direction, may produce sympathetic response of more distant lateral roots.

The influence of curvature of the main root upon the form and lateral deviation of the side roots, determined by NOLL and explained (?) as morphaesthesia, is due, according to NORDHAUSEN, to changes in the tension of the central cylinder,

[10] WITTE, H., Till de Svenska alfvarväxternas ekologi. pp. 119. Upsala. 1906.

[11] NORDHAUSEN, M., Ueber Richtung und Wachstum der Seitenwurzelen unter dem Einfluss äusserer und innerer Faktoren. Jahrb. Wiss. Bot. **44**:557–634. 1907.

particularly of the pericambium. He finds these effects producible by injuries, depression of turgor, etc., which need only act in the past, while the growth of the lateral roots takes place under regular conditions.—C. R. B.

**Soil fertility.**—Two recent bulletins from the Bureau of Soils deal with the question of the factors affecting soil fertility. One, by LIVINGSTON and others,[12] demonstrates the presence in unproductive soils of substances deleterious to plant growth. He adds the evidence gathered up to the close of his work that the toxic substances are apparently produced by the plants themselves growing in soil and water cultures. He finds that such toxic substances can be dissolved partly in a watery extract of soil and may be removed from such an extract by shaking with finely divided insoluble solids. This leads to the further suggestion, partly supported by experiment, that stable manure and green fertilizers are beneficial rather by their action on the soil constituents, than by either the salts or the organic matter put at the disposal of the plants. Incidentally it was found necessary to devise methods for securing non-toxic distilled water. The most satisfactory water was prepared by shaking ordinary distilled water with fine, clean carbon black or precipitated ferric hydrate and filtering.

Developing the idea suggested by LIVINGSTON'S work, SCHREINER and REED[13] show that the toxic substances originate from the plants themselves, diffusing from their roots. This they demonstrate by direct experiment with seedling wheat and other plants, and support by adducing experiments and observations which have been accumulating for years, and can be best explained by their experimental results. It appears, for example, that the excreta from no other roots were so harmful to wheat as its own, and that the excreta from oats were more harmful to wheat than those from the less closely related corn and cowpea. The natural succession of plants, the deleterious effects of grass sod on apple trees, oak-openings, fairy rings, crop rotation, the effects of good tillage, can all be rationally explained in the light of the facts adduced.

SCHREINER and REED have also published the substance of this bulletin in another paper which requires only citation.[14]—C. R. B.

**Items of taxonomic interest.**—A. A. HELLER (Muhlenbergia **2**:269–338. 1907), in an enumeration of plants collected in the coast region of California during 1907, describes new species in Limnia (Claytonia), Lathyrus, Lupinus, Trifolium, Amsinckia, Stachys (3), and Plectritis (2); and also proposes Heleniaceae, Anthemidaceae, and Senecionaceae as new families.—E. O. WOOTON and P. STANDLEY

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[12] LIVINGSTON, B. E. Further studies on the properties of unproductive soils. U. S. Dept. Agric., Bureau of Soils, Bull. 36. pp. 71. *pls.* 7. 1907.

[13] SCHREINER, O., and REED, H. S., Some factors influencing soil fertility. U. S. Dept. Agric., Bureau of Soils, Bull. 40. pp. 40. *pls.* 3. 1907.

[14] SCHREINER, O., and REED. H. S., The production of deleterious excretions by roots. Bull. Torr. Bot. Club **34**:279–303. 1907.

(Bull. Torr. Bot. Club **34**:517–520. 1907) have described 2 new species of Androsace from New Mexico.—M. L. FERNALD (Rhodora **9**:221–226. 1907) has described 3 new species and 2 new varieties of Salix from Eastern America.—K. YENDO (Jour. Coll. Sci. Univ. Tokyo **21**: art. 12. pp. 174. *pls. 18*. 1907) has published (in English) a full account, with excellent plates, of "The Fucaceae of Japan" (61 species), including new species in Cystophyllum (2), Coccophora, and Sargassum (2), and also a new genus (*Ishige*).—J. BRIQUET (Botanisk Tidskr. **28**:233–248. 1907), in describing the Labiatae from the Central Asian and Persian collections of OVE PAULSEN, describes a new genus (*Paulseniella*) in Stachyoideae.—S. KAWAMURA (Jour. Coll. Sci. Univ. Tokyo **23**: art. 2. pp. 12. *pls. 5*. 1907) has described a new genus (*Miyoshia*) of Ascomycetes parasitic on the stems of a species of bamboo.—C. WARNSTORF (Hedwigia **47**:113–127. 1908) has described the following new species of Sphagnum from the U. S.: *S. Mehneri* (Alaska), *S. Faxonii* (Mass.), and *S. riparioides* (Alabama).—A. W. EVANS (Torreya **7**:225–229. 1907) has described a new genus (*Leucolejeunea*) of Hepaticae, segregated from Archilejeunea and containing 5 species.—H. D. HOUSE (*idem* 233–235) has discovered that the generic name Shortia cannot be maintained for the interesting *S. galacifolia* of the southern Appalachians, on account of an earlier Shortia of RAFINESQUE; accordingly the name *Sherwoodia* is proposed and the names of the one American and the three Asiatic species are transferred.—W. W. EGGLESTON (*idem* 235, 236) has described a new Crataegus from New Mexico.—A. NELSON and P. B. KENNEDY (Muhlenbergia **3**:137–143. 1908) have described new species from the Great Basin in Lepidium, Boisduvalia, Chylisma, Oreocarya, Phlox, Plantago, and Symphoricarpos.—F. RAMALEY (Univ. Col. Studies **5**:47–63. 1907), in a list of the woody plants of Boulder County, Col., including the ranges, enumerates 112 species in 50 genera.—TH. VALETON (Bull. Depart. Agric. Ind. Néerland. 10. pp. 70. 1907), in a list of Papuan plants, describes 21 new species.—N. L. BRITTON (Bull. Depart. Agric. Jamaica **5**: suppl. 1. pp. 19. 1907) has published a list of the sedges of Jamaica, enumerating 96 species, 37 of which belong to Cyperus.—G. MASSEE (Trans. N. Z. Inst. **39**:1–49. *pls. 1, 2*. 1907), in his second paper on the fungus flora of New Zealand, presents the Polyporeae (9 gen., 47 spp.), Hydneae (4 gen., 8 spp.), Thelephoreae (10 gen., 36 spp.), Clavarieae (2 gen., 11 spp.), and Tremellineae (9 gen., 15 spp.).—OAKES AMES (Philipp. Jour. Sci. **2**:311–337. 1907) has published a list of the orchids of Mount Halcon and vicinity, Mindoro, 93 species being named, 39 of which are new.—C. S. SARGENT (Rep. Mich. Geol. Survey **1906**:515–570. 1907) has published an account of the species of Crataegus in Southern Michigan, recognizing 55, of which 24 are described as new.—J. M. GREENMAN (Field Columb. Mus. Publ. Bot. Ser. **2**:247–287. 1907) has published the results of his study of recent collections from Mexico, Central America, and the West Indies. The species number 92, of which 35 are described as new, one of them constituting a new genus (*Goldmania*) of Coreopsideae. Of Senecio 28 species are presented, 7 of which are new, and 18 of which are fully characterized for the first time.—J. M. C.

**Anatomy of Tmesipteris.**—Miss SYKES[15] has investigated this interesting genus from material sent by Mr. A. P. W. THOMAS of New Zealand, comprising the two species *T. tannensis* and *T. lanceolata*. The genus consists of epiphytic species on tree ferns in New Zealand, Australia, and Polynesia. Only adult plants have ever been obtained, and the gametophyte is entirely unknown. Naturally the investigation by Miss SYKES has to do chiefly with the anatomy, and an outline of her results is as follows, in part confirmatory of previous work.

In the rhizome there occurs a protostele, which has usually two exarch protoxylem groups, but in passing to the aerial branch, pith arises in the center of the stele and quickly expands to form a large tissue. This is a case of a protostele passing directly into an ectophloic siphonostele, without the intermediate stage of an amphiphloic siphonostele; and all this occurs at a level at which no leaves have yet arisen. It was discovered that the course of the vascular bundles as described by BERTRAND for a sterile branch is exactly similar to that found in a fertile branch; that is, the single bundle entering the axis branches into three, the two lateral traces supplying the leaves, and the central one representing the vascular supply of the apex. In the fertile branches the central bundle supplies the synangium, and indicates to the author that the so-called "sporophyte" is cauline in nature, consisting of an axis bearing two leaves, and at its apex a synangium formed of two masses of sporogenous tissue that have fused over the tip. Attention is called also to the essential similarity in the formation of leaf and branch traces, it being claimed that the presence of a gap depends simply on the greater length of time elapsing between the division of a xylem group to form a trace and the departure of that trace from the stele. In fact, if the so-called "sporophyll" is really a sporophyll, the exit of its trace results in a leaf-gap; but according to Miss SYKES this is a branch-gap. The conclusion as to relationship, apparently inevitable in all such pieces of work, is that the Psilotaceae had better be retained as a separate division of Pteridophytes, the Psilotales.—J. M. C.

**Rôle of certain elements.**—The precise physiological rôle which the essential chemical elements play in plant life has long been an attractive subject for investigation. With advancing chemical knowledge the methods of experimentation have been greatly improved. It must be said that the older experiments have little value, and it is doubtful whether even the newest have very much, because the chemistry of the proteids is still such an enigma. REED has undertaken the study of the effects of four elements, potassium, phosphorus, calcium, and magnesium, upon certain filamentous algae, protonemata of mosses, prothallia of ferns, root tips of seed plants, and filaments of Basidiobolus.[16] His technique contains certain improvements; at the same time, on the score of the solutions used, it is

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[15] SYKES, M. G., The anatomy and morphology of Tmesipteris. Annals of Botany **22**:63–89. *pls. 7, 8. figs. 13.* 1908.

[16] REED, H. S., The value of certain nutritive elements to the plant cell. Annals of Botany **21**:501–543. *figs. 2.* 1907.

open to some objections, which, however, may be more theoretical than practical. From his observations on plants grown in the absence of certain salts, he draws conclusions as to the rôle of a particular element—a time-honored but nevertheless unsafe process. Some of these observations coincide with those of earlier observers, and others are to be added to the long list of specific effects previously recorded after like experiments. We cannot enumerate the results in detail. Assuming REED'S and all others as valid, no one is yet in a position to interpret this immense mass of data, many of them conflicting, and to frame any generalizations.

In his discussion REED clearly recognizes that the elements may either enter into the composition of some organ or substance in the cell, or without doing this permanently may act as catalysers, or in some other way may condition certain reactions. It is the varied possibilities within these categories that render useless at present all conclusions regarding the rôle of an element. The causal nexus is too intricate to be analyzed until far more knowledge of cell chemistry is available.—C. R. B.

**Respiration and potassium cyanid.**—Incited by the studies of animal physiologists on the effect of hydrocyanic acid and cyanids upon animal respiration, SCHROEDER set out to determine the effect of potassium cyanid upon the respiration of *Aspergillus niger*.[17] Of course "respiration" here means the intake of $O_2$ and the output of $CO_2$, processes which are quite independent of one another, and SCHROEDER'S results furnish further evidence, if any were needed, of this independence. Such investigations can hardly yield, as the author hopes, satisfactory "conclusions as to the chemism of vital functions," until it is possible to make a much more exact analysis of the fixation of $O_2$ and the evolution of $CO_2$ than is yet possible. Enough is known regarding the diverse sources of $CO_2$, however, to minify the value of superficial researches upon such obscure phenomena. The investigations themselves are extensive and thorough enough, but they necessarily deal with superficial phenomena.

SCHROEDER finds both the fixation of $O_2$ and the evolution of $CO_2$ strikingly reduced by potassium cyanid. The production of $CO_2$ is practically stopped, but the consumption of oxygen is not. The author is uncertain "whether this small intake of $O_2$ is to be considered as a vital process, or a purely chemical phenomenon," a phrase which indicates an unfortunate state of mind regarding "vital" processes. He does not think that the cessation of the evolution of $CO_2$ is a valid mark of death. (Obviously not, since it is well known that neither its evolution nor cessation has any definite relation to death.) The further distinctions which he makes between the action of HCN on the respiratory process "as a primary action . . . . and not as a phenomenon of death," seem quite invalid in view of our ignorance of the details of dissimilation.—C. R. B.

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[17] SCHROEDER, H., Ueber den Einfluss des Cyankaliums auf die Atmung von *Aspergillus niger*, nebst Bemerkungen über die Mechanik der Blausäure-Wirkung. Jahrb. Wiss. Bot. **44**:409–481. *figs.* 2. 1907.

**Compositae of Southern California.**—H. M. HALL[18] has brought together our present knowledge of the Compositae of Southern California, an area about the size of Pennsylvania. The 445 species and varieties are distributed as following among the tribes: Eupatorieae (9), Astereae (113), Inuleae (25), Ambrosieae (18), Heliantheae (34), Madieae (29), Helenieae (86), Anthemideae (19), Senecioneae (25), Cynareae (17), Mutisieae (2), Cichorieae (68). These numbers would be largely increased if the author were not very conservative in his conception of species. As it is, the contribution becomes a manual of readily recognized forms, which are further brought within easy reach by the numerous well-constructed keys. It is unusual to find in so extensive a contribution that only three new species have been described, two in Aster and one in Lessingia. However, there is large recognition of varieties, many new ones being proposed; and new combinations are frequent. The reduction of numerous names to synonymy may be a service or may add to the confusion, dependent upon the care with which the types were studied. In any event, this type of monograph for so interesting a region is to be commended.—J. M. C.

**Nuclear division in Zygnema.**—ESCOYEZ[19] has published the results of cytological studies on Zygnema. The conclusions are as follows: (1) A chromatin network forms chromosomes by gradual concentration. (2) The nucleolus contains no chromatin substance and does not furnish any morphological elements to the chromosomes. (3) The chromosomes are not formed by the fusion of four groups of chromatin granules, as was claimed by Miss MERRIMAN. (4) The chromosomes split longitudinally in the metaphase as in typical mitosis. (5) In the telophase the chromosomes first become massed at the poles and then vacuolated. The anastomosed structure of the nucleus consists entirely of chromosomes. (6) The nucleolus is not formed by the confluence of chromosomes, but appears quite independent of the chromatin network. (7) There is formed no continuous spirem, and the chromosomes evidently keep their individuality. (8) Pyrenoids and chromatophores divide simply by constriction, and the division is independent of that of nucleus. The division of the two pyrenoids does not necessarily occur simultaneously.—S. YAMANOUCHI.

**The double leaf trace.**—Miss THOMAS[20] has brought together the facts in reference to the double leaf-trace, so characteristic of the ancient fern and older gymnosperm series, and well marked in the living cycads. This condition is claimed to exist in the "double bundle" of the cotyledons of angiosperms, and is of very frequent occurrence in modern ferns. A phenomenon of such wide occurrence suggests "the existence of a common cause of a fundamental and primitive character," and this the author finds in dichotomous branching; which means

[18] HALL, H. M., Compositae of Southern California. Univ. Calif. Publ. Bot. **3**:1–302. *pls.* 1–3. 1907.

[19] ESCOYEZ, EUD., Le noyau et la caryocinèse chez le Zygnema. La Cellule **24**:356–366. *pl.* 1. 1907.

[20] THOMAS, ETHEL N., A theory of the double leaf-trace founded on seedling structure. New Phytologist **6**:77–91. *figs.* 4. 1907.

that the double leaf-trace "is neither more nor less than an early dichotomy of the vascular system of the leaf." This persistent dichotomy of the leaf-trace, long after dichotomy has disappeared from the leaf, is used to explain the irregular dichotomy of the leaves of Cycadofilices, the dichotomy of the early leaves of modern ferns, the splitting of cotyledons in polycotyledony; and "it finds its latest expression in the 'double bundle' of the cotyledons of angiosperms." This view certainly helps to connect the angiosperms with the same old fern stock that gave rise to the gymnosperms.—J. M. C.

**Effect of electricity.**—A very concise summary of the work previously published upon the effect of electricity on the growth and development of plants is furnished by PRIESTLEY[21] as the preface to a brief account of some recent experiments on a large scale by NEWMAN near Bristol, Gloucester, and Evesham. The current used was of high tension, distributed by overhead wires from which depended metallic points. In general the results show a very decided increase in the quantity, or quality, or earliness of the crop. Thus year-old strawberries showed 80 per cent. increase, Canadian Red Fife wheat 39 per cent. The electrified wheat produced a better baking flour and consequently sold at 7.5 per cent. higher prices. Electrified beets not only showed 33 per cent. increase in the crop, but contained over 14 per cent. more sugar. Currents traversing the earth produced occasionally increase in rate of growth, but often had no definite effect. The physiological action of the current is not clear. PRIESTLEY rejects POLLACCI's view that it enables the green plant to elaborate starch in the dark.—C. R. B.

**A theory of photosynthesis.**—GIBSON outlines[22] thus a photoelectric theory of photosynthesis, which he is to elaborate later in cooperation with two colleagues: The light rays absorbed by chlorophyll are transformed by it into electric energy which effects the decomposition of $H_2CO_3$, with the concomitant formation of an aldehyde and the evolution of oxygen. He finds a small quantity of formaldehyde present, as shown by the test of MULLIKEN, BROWN, and FRENCH, in all actively photosynthetic tissues, the amount being definitely related to the illumination. The maximum decomposition of $CO_2$ occurs in light equal to one-quarter direct sunlight. H.COH may be synthesized from $CO_2$ in the presence of water by a silent electric discharge, as LOEB has shown; and this GIBSON confirms. Electric discharges of sufficient intensity have already been found in adequately illuminated green tissues, and the light rays absorbed by chlorophyll are the ones which produce these currents. He promises in the forthcoming paper to connect formaldehyde with carbonic acid by a photolytic method which is above suspicion. —C. R. B.

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[21] PRIESTLEY, J. H., The effect of electricity upon plants. Proc. Bristol Nats. Soc. IV. 1:192–203. 1907.

[22] GIBSON, R. J. HARVEY, A photoelectric theory of photosynthesis. Annals of Botany 22:117–120. 1908.

# NEWS

ABOUT 20,000 sheets were added to the Kew Herbarium during 1907, 7000 of which were purchased.

R. H. LOCK, Cambridge University, has been appointed assistant director at the Royal Botanic Gardens of Peradeniya, Ceylon.

DR. CHARLES J. CHAMBERLAIN, University of Chicago, spent the month of March in Mexico in further study of Dioon and Ceratozamia.

AT THE MEETING of the British Association in Dublin next September, FRANCIS DARWIN will be general president, and F. F. BLACKMAN president of the section of botany (K).

THE SWEDISH ACADEMY OF SCIENCES has granted to Professor C. F. O. NORDSTEDT 1000 kronor ($270) for the purpose of printing a supplement to his *Index Desmidiacearum*.

DR. MAX KÖRNICKE, *privat-docent* in the University of Bonn, has been appointed to succeed Professor L. JOST as the professor of botany in the Agricultural College at Bonn-Poppelsdorf.

PROFESSOR SERGIUS NAWASCHIN, of the University of Kieff, completed on March 3 last twenty-five years of service as a teacher. The Society of Naturalists of Kieff on that day elected him an honorary member and arranged for further celebration of the occasion.

DR. J. N. ROSE, of the U. S. National Herbarium, left Washington March 17 for an extended trip through Texas, New Mexico, Arizona, southern California, and northern Mexico, for the purpose of studying Cactaceae in the field. His headquarters are at the Desert Laboratory at Tucson, Arizona.

"L'ASSOCIATION INTERNATIONALE DES BOTANISTES" will hold its next meeting at the University of Montpellier, beginning June 7, 1908, the meetings of standing committees being announced for the preceding day. Most attractive excursions are being planned. Members who intend to be present are urged to notify Professor FLAHAULT as soon as possible.

THE HERBARIUM of Dr. OTTO KUNTZE has been secured for the New York Botanical Garden, through the generosity of Mr. ANDREW CARNEGIE. It is estimated that the collection contains over 30,000 specimens, from all parts of the world. To American botanists the greatest interest of this collection is that it contains a large number of type specimens of tropical American and South American species.

A BIOGRAPHICAL SKETCH, with portrait, of the late GEORGE E. DAVENPORT, who died November 27, 1907, at the age of 74 years, is published in *Rhodora* (10:1–9. 1908), prepared by F. S. COLLINS. A list of his botanical writings includes 109 titles. Mr. DAVENPORT'S contributions to the BOTANICAL GAZETTE

began with the second volume, and in the early volumes 28 contributions are credited to him.

GEBRÜDER BORNTRAEGER announce the inception of a new journal, *Zeitschrift für induktive Abstammungs- und Vererbungslehre*, under the editorship of Dr. E. BAUR (Berlin) and the general direction of CORRENS, HAECKER, STEINMANN, and VON WETTSTEIN. It will appear in octavo parts of variable size (how many are to form a volume is not stated, nor is the price announced), and is to contain contributions to the theory of evolution, whether from the field of paleontology, biology of living forms, taxonomy, physiological chemistry, or experimental evolution.

THE BOTANICAL PROGRAMME (February 14) of the Wisconsin Academy includes the following titles: Nuclear division in the vegetative cells of *Gentiana detonsa*, by R. H. DENNISTON; The blepharoplast in the development of the antherozoid in ferns, by RUTH F. ALLEN; Variations in macrospore formation in *Smilacina stellata*, by FRED MCALLISTER; Nuclear division and spore formation in Geoglossum, by HALLIE D. M. JOLIVETTE; Nuclear structure and nuclear division in *Chrysomyxa ledi*, by R. A. HARPER; The development of the male cells of a moss, by C. E. ALLEN.

DR. FRIEDERICH KÖRNICKE, Geheimer-Regierungsrat and professor in the Landwirthschaftliche Akademie at Bonn from 1867 to 1898, when he retired as *emeritus*, died on January 16, at the age of 80. He was a native of Pratau, near Wittenberg, studied under KUNTH, LINK, and ALEXANDER BRAUN in Berlin, where he served as assistant for seven years. After three years in St. Petersburg he went in 1859 to the agricultural school at Waldau, and in 1867 to Bonn. He was the author of monographs on Eriocaulaceae, Rapataceae, and Marantaceae. His important work, *Die Arten und Varietäten des Getreides*, was published at Bonn in 1885.

PROFESSOR W. A. KELLERMAN, in charge of the Department of Botany at Ohio State University, Columbus, died on March 8 in Guatemala from an attack of malarial fever, at the age of 57 years. Last December he went to Central America with a party of students to collect parasitic fungi and to study tropical vegetation, and this sudden death is a sacrifice to scientific zeal. His publications include such books as *The flora of Kansas*, a text book entitled *Elementary botany*, and numerous papers; but he was chiefly interested in the *Journal of Mycology*, of which he was editor and proprietor, and in the more recently established *Mycological Bulletin*, to which he held the same relation. He was a native of Ohio, graduated at Cornell University in 1871, received his doctor's degree at the University of Zurich in 1881, and held positions in a state normal school of Wisconsin, the State Agricultural College of Kansas, and the State University of Ohio, where he was in charge of the botany since 1891. Professor KELLERMAN was not only an enthusiastic student of his chosen subject, but he was also a man of fine and genial presence, who attached to himself all those who came into personal relations with him.